ASTRONOMY

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Celestial Views of Planet Earth

Comet Halley's Surprising Last Stand

Camera Lenses for Deep-Sky Photography

A Supernova in Centaurus A

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MEADE SUPER PLÖSSL 56mm
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Design Specifications: Meade Series 4000 eyepieces yield the widest possible fields of view, consistent with pinpoint edge-of-field sharpness and long eye relief, and yet with extremely low astigmatism, spherical aberration, and off-axis color. Incorporating 7-layer multicoatings and edge-blackened optics for optimal image contrast, these sophisticated 5- to 8-element designs permit levels of optical corrections virtually impossible to achieve with eyepieces of fewer elements. The polished chromed-brass barrels are threaded for standard filters, and, where practical (see table), eyepieces and both Barlow lenses are parfocal, allowing eyepiece interchangeability without refocusing.

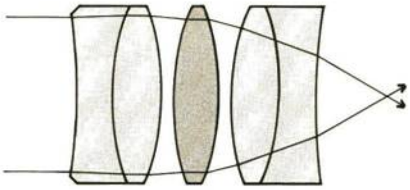
Eyepiece Groups: Eighteen focal lengths in the three Series 4000 eyepiece groups permit precisely the right eyepiece for any application. Whether your telescope is an f/4 Newtonian, an f/10 Schmidt-Cassegrain, or an f/16 refractor, its performance will benefit by using these incredible oculars:

Super Plössls: With 5 optical elements rather than the traditional 4, Meade Super Plössls provide a 40% improvement in corrections for chromatic aberration and edge-distortions over any other premium Plössls. Best for general observing at moderate cost, the Super Plössl eyepieces are perfect optical complements for the Series 4000 air-spaced Barlows, below. Try the 56mm on your 8" Schmidt-Cassegrain for an actual field of over 1.4° at 36X!

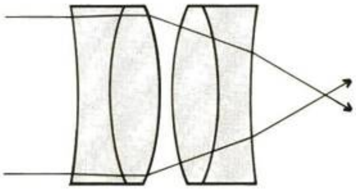
Super Wide Angles: These 6-element eyepieces, with their 67° fields, offer exquisite wide-angle images at low to medium powers, ideal for star fields, galaxies, and other deep-space phenomena. Focal lengths with 1¼" barrels yield extremely high-resolution, high-power lunar and planetary images when combined with one of the Series 4000 Barlows.

Ultra Wide Angles: The ultimate in modern eyepieces, Meade 8-element Ultra Wide Angles permit extreme image fidelity and sharpness over an amazing 84° apparent field: for moderate to high power applications, no other eyepieces come close. A magnificent optical match with Schmidt-Cassegrains and fast Newtonians.

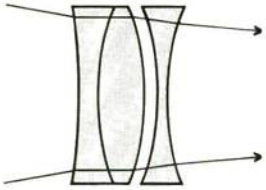
Series 4000 Barlow Lenses: The most sophisticated Barlows ever developed for commercial telescopes, these 2X and 2.8X Telenegative Amplifiers include 3-element, air-spaced, multi-coated optics, unmatched in image resolution and color correction. Both models optically complement the Series 4000 eyepieces, while significantly enhancing the performance of other eyepieces as well.



Meade 5-element Super Plössl design: the central lens element enables significant reductions in chromatic aberration and edge-distortions over other premium Plössl designs.



Other premium Plössls: include only the traditional 4-elements.



Meade Series 4000 Barlows: 3 elements, air-spaced, instead of the standard 2 non-air-spaced elements.

Series 4000 Eyepieces and Barlows

Super Plössls (5-elements)	APPARENT FIELD	BARREL DIA.	PARFOCAL
6.4mm	52°	1¼"	Yes
9.7mm	52°	1¼"	Yes
12.4mm	52°	1¼"	Yes
15mm	52°	1¼"	Yes
20mm	52°	1¼"	Yes
26mm	52°	1¼"	Yes
32mm	52°	1¼"	Yes
40mm	44°	1¼"	No
56mm	52°	2"	No
Super Wide Angles (6-elements)			
13.8mm	67°	1¼"	Yes
18mm	67°	1¼"	Yes
24.5mm	67°	1¼"	Yes
32mm	67°	2"	No
40mm	67°	2"	No
Ultra Wide Angles (8-elements)			
4.7mm	84°	1¼"	Yes
6.7mm	84°	1¼"	Yes
8.8mm	84°	1¼" & 2"	Yes
14mm	84°	1¼" & 2"	No
Barlow Lenses (3-elements, air-spaced)			
#140 2X Telenegative Amplifier		1¼"	Yes
#142 2.8X Telenegative Amplifier		1¼"	Yes

Meade 2" Mirror Diagonal: For attachment to Schmidt-Cassegrain telescopes, the 2" Mirror Diagonal permits use of Series 4000 eyepieces with 2" barrels. The 1/10-wave-flat Pyrex mirror, manufactured at the Meade Costa Mesa optical facility, is multi-coated with enhanced aluminum for maximum reflectance. An adapter for 1¼" eyepieces is included.

Where To Buy: Meade Series 4000 eyepieces and Barlows are available from over 600 authorized Meade dealers in the U.S.A. and Canada. Call us toll-free (see below) for your nearest dealer.

Prices: Notwithstanding their performance standards and optical sophistication, Meade Series 4000 eyepieces and Barlows are priced very competitively with other premium oculars and Barlows.

Warranty: All Series 4000 systems are covered by the Meade Limited Lifetime Warranty—the most extensive in the industry. See the Meade catalog for details.

New 1986 Meade General Catalog 86-C: $3.00

Just-published, the new Meade 1986 General Catalog includes complete information on the full range of Meade astronomical products, along with a supplement on **"How To Choose Your Eyepieces."** Send $3.00 for your copy.

U.S. and Canada Dealer Locations & Assistance

For your nearest Meade dealer location, or for free telescope information and assistance, call Meade Instruments **toll-free** from anywhere in the continental U.S.A., (except Calif.):

1-800-854-7485

From all other areas, including California, call direct: **(714) 556-2291**

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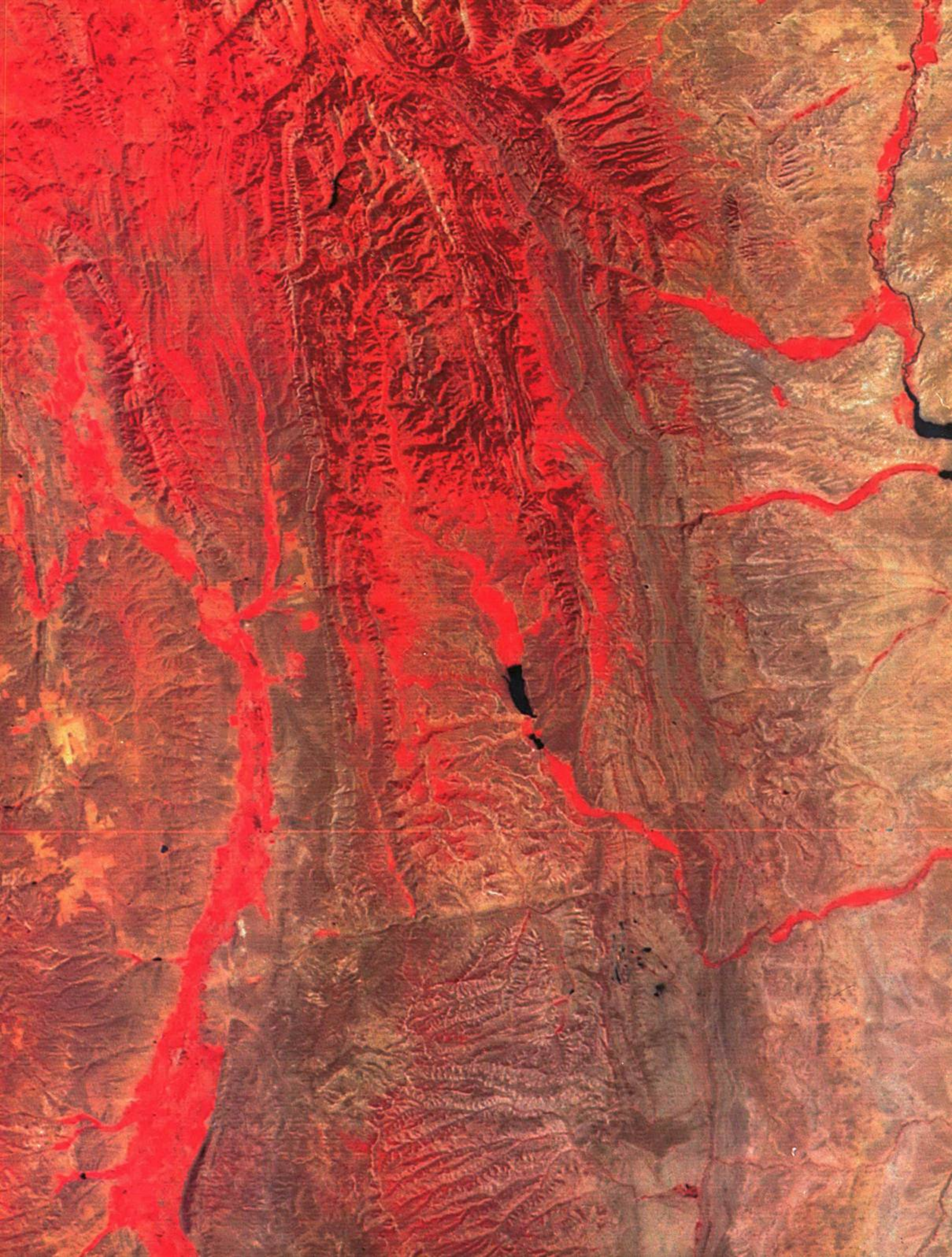

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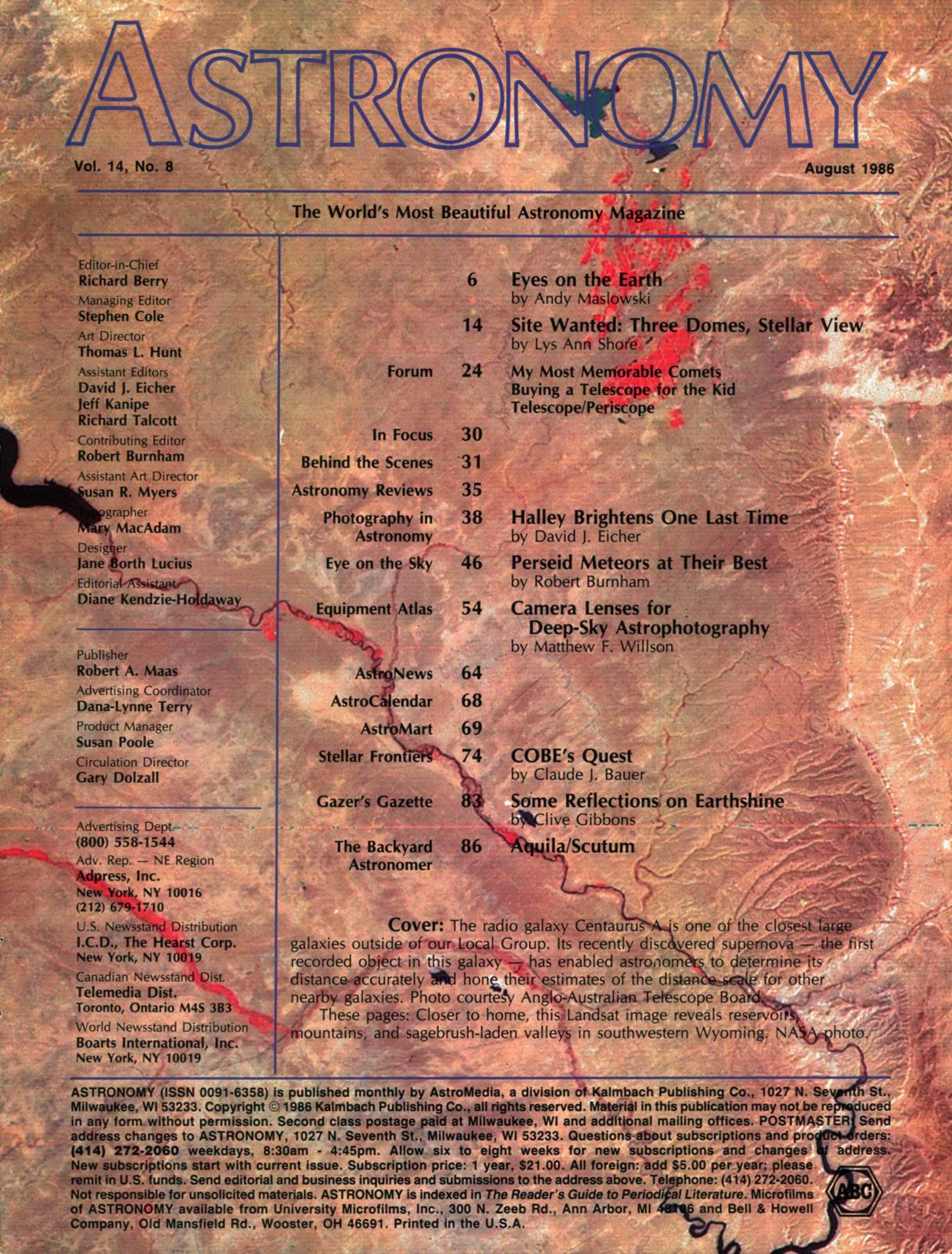

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Cover: The radio galaxy Centaurus A is one of the closest large galaxies outside of our Local Group. Its recently discovered supernova — the first recorded object in this galaxy — has enabled astronomers to determine its distance accurately and hone their estimates of the distance scale for other nearby galaxies. Photo courtesy Anglo-Australian Telescope Board.

These pages: Closer to home, this Landsat image reveals reservoirs, mountains, and sagebrush-laden valleys in southwestern Wyoming. NASA photo.

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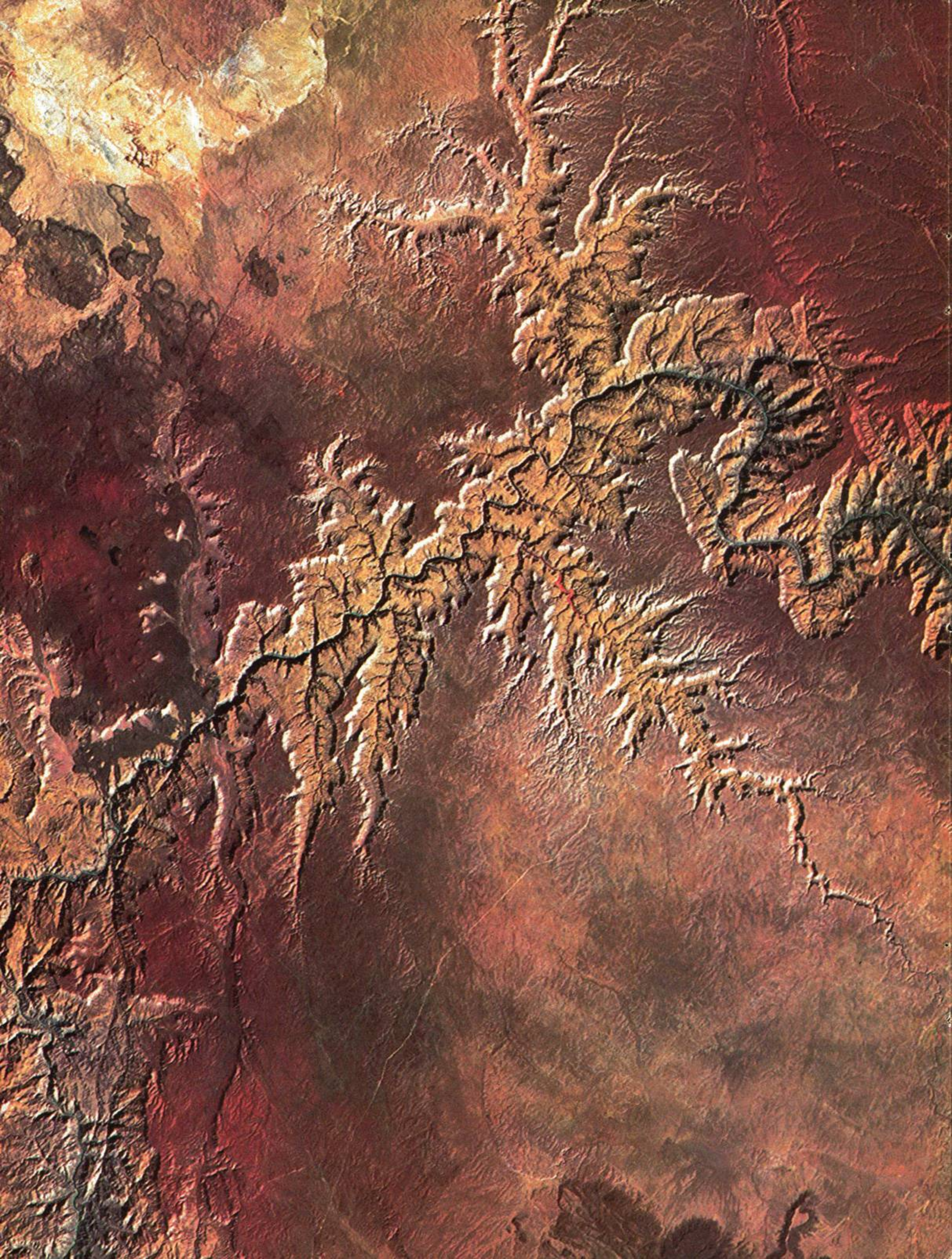
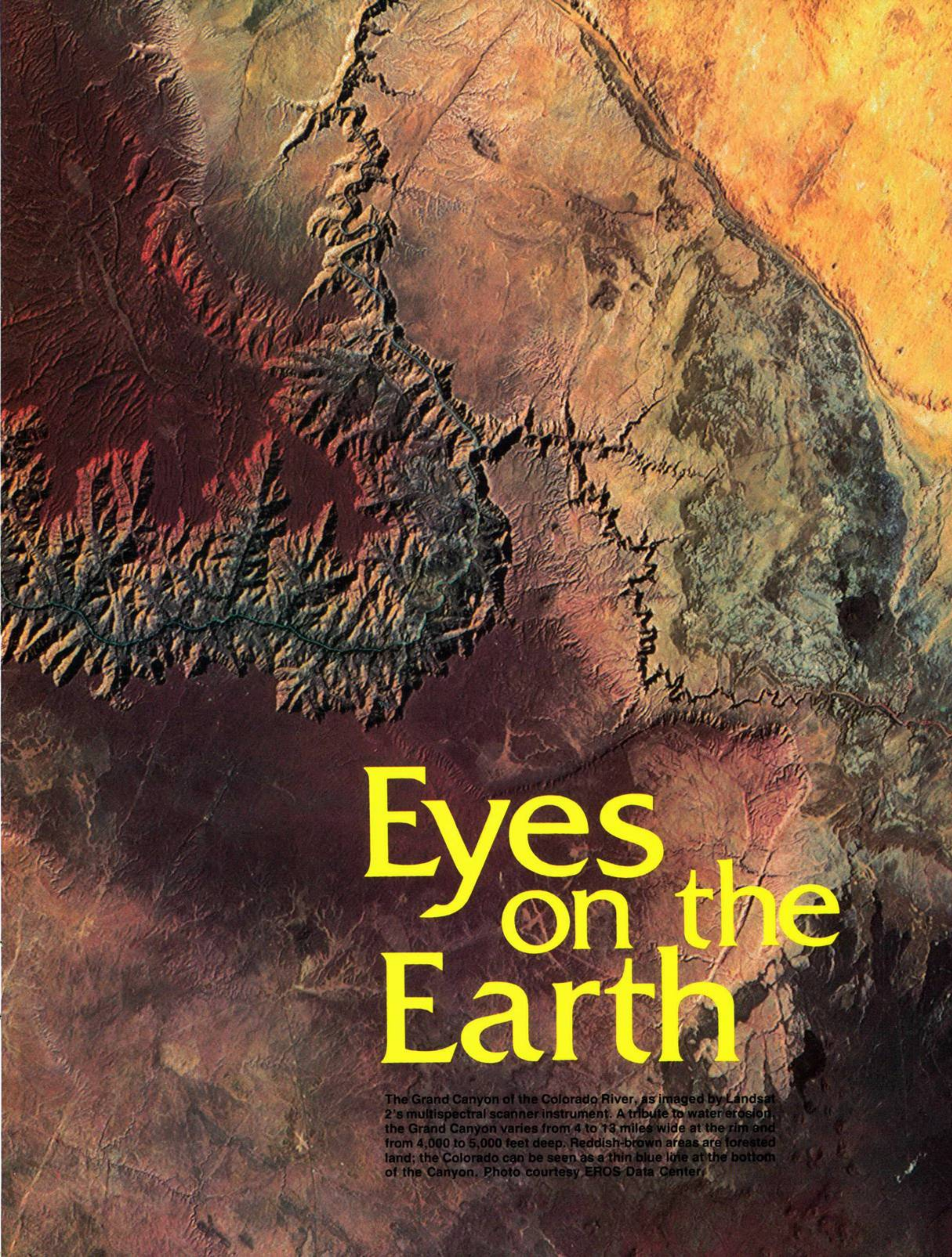


Eyes on the Earth



The Grand Canyon of the Colorado River, as imaged by Landsat 2's multispectral scanner instrument. A tribute to water erosion, the Grand Canyon varies from 4 to 13 miles wide at the rim and from 4,000 to 5,000 feet deep. Reddish-brown areas are forested land; the Colorado can be seen as a thin blue line at the bottom of the Canyon. Photo courtesy EROS Data Center.

Eyes on the Earth

by Andy Maslowski

Landsat satellites continue to tell us about the surface of our planet.

The systematic study of our planet from space has benefited greatly from NASA's latest Earth resource satellite, Landsat 5. Launched on March 1, 1984, Landsat 5 circles our planet every 99 minutes in a polar orbit 435 miles (700 kilometers) above the surface. From its high vantage point, Landsat 5 collects valuable data on mineral resources, vegetation, atmospheric conditions, and water and air pollution for the benefit of all the inhabitants of Earth.

Landsat 5 is the fifth and most recent Landsat; the first was launched in 1972. Each mission has been more sophisticated than the one before it, and future Earth-resources missions will undoubtedly be even better. Landsat 5 is a squarish-looking spacecraft 15 feet long by 7 feet wide weighing 2 tons. It transmits picture data to Goddard Space Flight Center in Maryland and other ground stations from a steerable 6-foot diameter antenna.

The main instrument on board Landsats 1, 2, and 3 was a multispectral scanner (MSS), essentially a fancy facsimile camera. As the satellite passed overhead, a mirror scanned Earth's surface in four different colors: green, red, and two bands in the infrared.

Landsat MSS images were a revelation to Earth scientists, literally turning our planet into a giant geology lab. For Landsats 4 and 5, the MSS instrument has been updated and improved. The model aboard these orbiters resolves features on the ground as small as 80 meters (270 feet), or the size of a football field. Each picture covers a swath 115 miles wide.

After years of working with not-quite-good-enough MSS images, a new instrument called the Thematic Mapper (TM) promised to make images almost three times sharper than MSS images. The first Thematic Mapper was placed on Landsat 4. In addition to 30-meter (98-foot) resolution, the Thematic Mapper "sees" seven spectral bands in the visible and infrared regions — an important bonus for many remote sensing programs. The TM has two bands in the green, one in the red, three in the near infrared, and one for the thermal infrared, or heat radiation.

Unfortunately, due to a power problem in its solar panels, Landsat 4 did not have enough on-board power to operate the Thematic Mapper, so this powerful sensor transmitted only a limited number of scenes between August 1982 and February 1983. As Lawrence Youngren of the National Oceanic and Atmospheric Administration's Earth Resources Observation Systems (NOAA/EROS) satellite data unit in Sioux Falls, South Dakota, confessed, "We have no way of determining the functional lifetime of any Landsat spacecraft. Landsat 4 [was] limited to acquiring MSS data only because of power constraints in its solar array."

The Thematic Mapper represents a new generation in civilian remote-sensing. (Since NASA is a civilian agency, it is not allowed to orbit sensors with resolution approaching military capabilities.) To make up for the loss of the Landsat 4 Thematic Mapper, NASA launched Landsat 5 in March 1984 with an identical TM instrument on board. So far, the device has performed flawlessly. According to Youngren, "Landsat 5 continues to fill its complete MSS and TM mission."

Landsat Products

The MSS and TM sensors on board the Landsat satellites measure the amount of energy reflected or emitted from features on the Earth's surface in a particular part of the electromagnetic spectrum and then transmit the data to Earth. With the aid of the powerful image-processing abilities of modern computers, the energy data is transformed into photographs.

SPOT: The Competition

EOSAT and Landsat are no longer alone in the Earth-observation business. The SPOT Image Corporation, a firm based in Toulouse, France, launched its first high-resolution Earth-observation satellite, SPOT-1, on February 22, 1986. It has already returned tens of thousands of Earth images.

SPOT's 10-meter (33-foot) resolution, which is three times better than Landsat's Thematic Mapper, guarantees SPOT a competitive place in the market. The SPOT program now includes four satellites that will provide a constant flow of high-resolution images through the late 1990s.

Original Landsat "film products" are black-and-white film positives, one for each of the spectral bands. To accentuate particular features, several black-and-white images can be combined, using color filters, onto color film or processed directly into composite false-color images by the computers.

Most Landsat images are processed to have characteristics of color infrared photos. Healthy green vegetation appears red as a result of its high infrared reflectivity; concrete and asphalt are blue or gray; deep, clear water appears black; shallow water or water carrying sediment is lighter and bluer.

For convenience in handling, Landsat's 115-mile-wide (185-kilometer) swath is cut into 115-mile-long sections, so each frame covers about 13,000 square miles. The standard image size has a scale of 1:1,000,000. At this scale the 115-mile-square tract is reduced to 7.3 inches (185 millimeters) square. Images at 1:500,000 and 1:250,000 scales are available as images 14.6 inches (371mm) and 29.2 inches (742mm) square.

MSS and TM images are available for most parts of the United States and many other areas around the world. According to spokeswoman Phyllis Wiepking, different images can be obtained from the NOAA/EROS data center. (See sidebar on page 10.) You have your choice

Good enough for geological features and crop analysis, the multispectral scanner's resolution falls short of what analysts would like in "cultural features," i.e., detailed land use in cities. Red areas are crops; blue and gray areas are concrete, asphalt, and buildings. This image of Detroit courtesy of the Environmental Research Institute of Michigan.

of a variety of spectral "bands," image scales, and spectral band combinations.

Getting the Most from Landsat

"Landsat data has made its major contribution to hydrocarbon exploration," says chief geologist John Everett of the Earth Satellite Corporation in Chevy Chase, Maryland. Numerous private companies purchase computer-compatible tapes of Landsat data for individual custom computer processing and to extract information from Landsat images — information that doesn't show up in the standard processing.

"Viewing over 34,000 square kilometers of the Earth's surface on a single Landsat image permits the detection and mapping of major regional structures associated with the geological development of entire geologic provinces," says Everett. "And through special digital enhancements it is also possible to map some of the more subtle surface expressions."

Everett has used Landsat imagery in a number of well-explored areas, including the Rocky Mountains and Oklahoma. "We use an integration of a geologic understanding of hydrocarbon accumulation in the area and subsurface data obtained for seismic surveys or other wells drilled in an area with Landsat interpretation." Everett is quick to add that Landsat data is only an aid to this exploration and cannot be used by itself to pick new drilling sites.

Getting In Touch

To have a geographic search conducted for image availability or for additional information, contact Customer Services, EOSAT, c/o EROS Data Center, Sioux Falls, SD 57198. Their telephone number is (605) 594-6151.

For more information about the Environmental Research Institute of Michigan and its international conferences on remote sensing for resource and environmental assessment, as well as conferences on exploration geology, contact: ERIM, P.O. Box 8618, Ann Arbor, MI 48107. Their telephone number is (313) 994-1200.

For more information on EOSAT's Landsat services, contact: EOSAT, 4300 Forbes Blvd., Lanham, MD 20706. Their telephone number is (800) 344-9933.

He also notes that the TM data has some advantages over the MSS data. "The higher resolution of the TM can sometimes pick out subtle features not visible on some MSS images," he says. "If we notice an area from the older MSS data that we thought was interesting, we like to detail it with the TM data."

Structural features such as folds, faults, dips, and strikes of particular rock formations, lineaments, landform and drainage patterns, and other anomalies suggest possible hydrocarbon traps to the trained eye of the geologist. Other natural resources can also be examined on Landsat images, as can agriculture and forestry.

Despite years of operational experience, new methods of Landsat interpretation are being researched and applied to many different disciplines by a variety of industrial, governmental, and academic concerns.

Landsat's Thematic Mapper yields 30-meter ground resolution from orbital altitude, which is adequate for many types of urban analysis. This image, for example, reveals four airfields: Sacramento Metropolitan Airport, McClellan Air Force Base, Mathes Air Force Base, and the Sacramento Executive Airport. The California state capitol building is visible as a white dot in the center of red-colored Capitol Park. NASA photo.

Overleaf: Geology, geology, and more geology. Landsat images portray the bare bones of our planet best of all. Although centered on Las Vegas, Nevada, this image shows the sedimentary rocks, outwash fans, and varied rock types of a desert landscape. Vegetation (in red), major highways, and reservoirs reveal the human presence. Photo courtesy of the Environmental Research Institute of Michigan.

The Environmental Research Institute of Michigan (ERIM) in Ann Arbor, Michigan, is one example. Established as a not-for-profit corporation by the Michigan State Legislature in 1973, the Institute's research activity usually involves modern remote sensing technology and associated data processing.

Spokesman Robert Rogers says ERIM has been concentrating its efforts on advanced digital image processing. "We do some interpretation and Landsat analysis and other support work for geologic remote sensing," he explains. "ERIM also conducts demonstration projects of image interpretation of certain areas."

Images for Sale

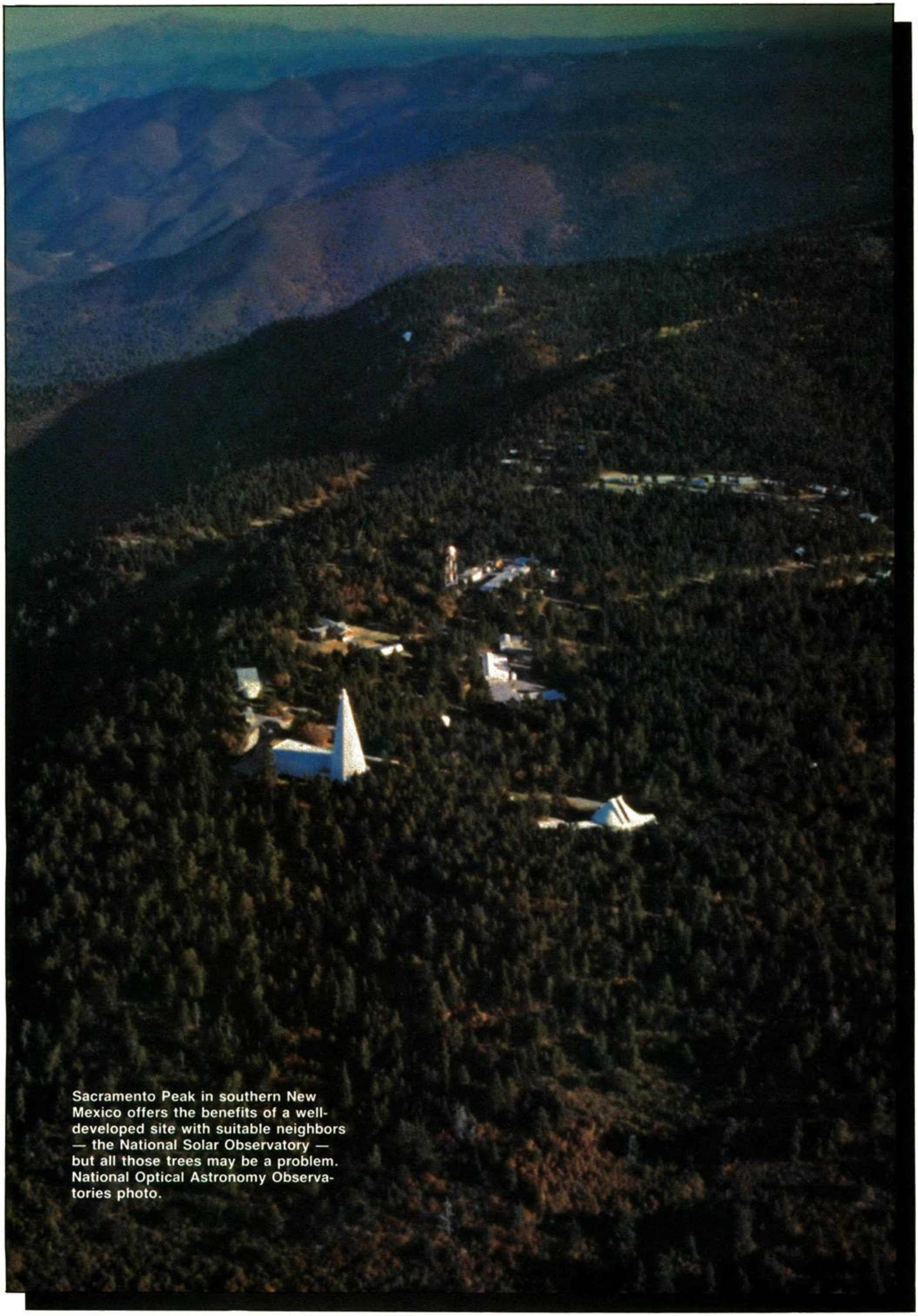
On September 27, 1985, Secretary of Commerce Malcolm Baldrige authorized a contract with the Earth Observation Satellite Company (EOSAT) to take control of the Landsat program. The phased transfer of the land remote sensing program from the federal government to the private sector was the result of the Land Remote Sensing Commercialization Act passed by Congress in June 1984.

Said Secretary Baldrige, "This is the time to transfer this program to the private sector. The American people have invested more than $1 billion in this system, and we hope to see their investment capitalized into private-sector jobs and opportunities here and overseas."

As part of its contract, EOSAT will undertake a ten-year program, beginning with the immediate assumption of operations of Landsats 4 and 5, and will be the primary point of contact for marketing, ordering, and distribution of the data from these spacecraft. Furthermore, EOSAT will receive a $250 million subsidy from the federal government to begin construction of the next generation of commercial Landsat vehicles. EOSAT has already announced that it plans to place its future sensing instruments aboard RCA's Omnistar, a Shuttle-serviced space platform with a twenty-year service life, rather than the current generation Landsat satellites that have a three-year lifetime.

"We can now get on with the business of making Landsat a viable commercial operation that will be used throughout the world in the development of renewable and non-renewable resources," says Charles P. Williams, EOSAT's president. "The contract signing represents a significant event in the future of space commercialization."

How much will a Landsat scene set you back? Prices may vary somewhat, but a 1:1,000,000-scale MSS color transparency costs $150, a Thematic Mapper color composite image sells for about $360, and a digital tape of a TM image runs about $3,300. It's quite a bargain.



Sacramento Peak in southern New Mexico offers the benefits of a well-developed site with suitable neighbors — the National Solar Observatory — but all those trees may be a problem. National Optical Astronomy Observatories photo.

Site Wanted: 3 Domes, Stellar View

Finding a home for a new observatory is somewhat less of a science than the astronomy that will be conducted there, as a group of astronomers recently discovered in New Mexico.

by Lys Ann Shore

"This isn't exactly a formal seeing test, you know — a bunch of astronomers all standing around saying, 'It looks good to me!'"

The speaker, grinning, is one of a group of a dozen astronomers gathered at the Capilla Peak Observatory in the Manzano Mountains of central New Mexico near sunset on a Friday evening in October 1985. Spirits are high because this evening marks the first stop on a three-part site visit that will span the entire weekend. Tomorrow they'll travel southwest to South Baldy in the Magdalena Mountains, then farther south and east to Sacramento Peak in the Sacramento Mountains. The purpose of the tour: to take a preliminary look at three possible sites for a new optical astronomical observatory.

The astronomers making the tour represent universities interested in forming a consortium, called the Large Telescope Consortium (LTC), to build a 3.5-meter (140-inch) reflecting telescope. Leading the group of visitors is Roberta M. Humphreys of the University of Minnesota, Minneapolis, who has taken the most active role in promoting and developing the project. Serving as local "tour guides" are astronomers from the University of New Mexico, Albuquerque, and the New Mexico Institute of Mining and Technology in Socorro, both consortium members.

The idea on this preliminary visit is to get a "typical" view of each site, see what towns affect the sky brightness, take water vapor readings, and, at Capilla, to perhaps open the dome and look through the observatory's finding telescope.

The sky darkens and soon the lights of Albuquerque are visible to the north through a gap in the mountains. Surprisingly, the lights of the small town of Belen, about 30 miles to the west, glow brightly. Just visible to the northeast are the lights of Santa Fe, New Mexico's capital, located about 60 miles northeast of Albuquerque.

Several people are engaged in setting up a water vapor meter to take a reading. The rest look, walk, and chat. Opinions pop into the frosty air like bubbles, and some burst just as quickly. "I'm used to Kitt Peak," says one, "and I can tell you this is an extremely dark sky." Another objects, "But look at all the light!" "There's a moon, for crying out loud!" replies the first.

The conversation turns to speculation about Sac Peak and South Baldy. "The lights of El Paso may hurt Sac Peak," someone predicts. The group will be able to check this prediction since they will spend Saturday night on Sac Peak before returning to Albuquerque on Sunday. They'll only get to see South Baldy by daylight, however, on this trip. The rendezvous has been set for early tomorrow morning in Socorro for the half-hour drive to the Magdalenas and up South Baldy.

Undeveloped Sites Are Expensive

The New Mexico mountains that the group will visit over this weekend aren't the only sites in the running. Hawaii's Mauna Kea, already the home of several observatories, is a possibility, as is Arizona's Mount Graham. Although both sites offer outstanding observing conditions, Mauna Kea is a remote location that is expensive to reach and Mount Graham is an undeveloped site. These are important considerations for a small-scale project, which this is. The entire project is tentatively budgeted at $10 million, which the Large Telescope Consortium hopes to raise primarily from private funds.

Membership in the LTC is still fluid. No one has had to put up any large amounts of money yet, and, in the end, that's what will determine membership. It's a little like buying stock in a corporation: a university's share in the project — and this includes telescope time — is proportional to its contribution.

The New Mexico sites, located in a sparsely populated state (1.3 million people) in the desert Southwest, offer dark skies and clear weather. Further, the three proposed sites are already developed.

Capilla Peak is reached by a gravel road that occasionally becomes impassable in bad weather. Although power lines reach the observatory, the staff must truck water up to the site. The University of New Mexico has operated a small observatory on Capilla Peak for more than twenty years that specializes in stellar photometry. The observatory is located at an elevation of about 9,300 feet in the Cibola National Forest, about 40 miles southeast of Albuquerque.

South Baldy, a 10,783-foot peak located 17 air miles southwest of Socorro, is reached by an unpaved road. Located on the ridge are New Mexico Tech's Irving Langmuir Laboratory for Atmospheric Research, the NASA-New Mexico Tech Joint Observatory for Cometary Research, and an automated supernova-search telescope constructed by New Mexico Tech astronomer Stirling Colgate. The site is equipped with both water and power lines.

Sacramento Peak is the home of the National Solar Observatory, located in Sunspot, New Mexico, about 70 miles northeast of Las Cruces. On a ridge three quarters of a mile south of the solar tower is Apache Point (9,215 feet), site of an observatory being constructed by a consortium led by the University of Washington, Seattle, and the University of Chicago. This well-developed peak is reached by an excellent road.

The LTC is seeking a site large enough to accommodate three domes and the necessary support structures, such as observers' quarters. The group intends to build one 3.5-meter reflecting telescope initially, but from the start of their planning they've kept in mind the desirability of expansion.

"I think it's realistic to talk about three telescopes," says Humphreys, "and I'd like three similar telescopes." You achieve certain economies of scale in duplicating a telescope, she explains, as well as reducing maintenance costs. "You don't need three times the staff to operate three telescopes."

Size of the site, ease of access, and availability of power and water — these logistical considerations come right behind the essential scientific criteria in choosing a site. After all, if a site doesn't promise excellent observing conditions, the fact that it has good roads and plenty of power and water may indicate only that it has great potential as a mountain resort.

Scientific Requirements of a Site

What makes a truly great site for an optical astronomical observatory? Although astronomers generally agree on three or four crucial factors, each one ranks them a little differently, depending on his or her research interests and personal experience. These are the essentials: good seeing, dark skies, clear nights, and, for infrared work, dry air.

Robert D. Gehrz, a University of Minnesota infrared astronomer, places good seeing first followed by dry air and dark skies. "You might have to put up with some clouds in order to get the other three factors," he says. Humphreys, an optical astronomer, ranks the number of clear nights first. "The most frustrating thing of all to an observer is getting capped," she says, "especially when you know from weather reports that it's clear in the valley." Terry Jones, another University of Minnesota infrared astronomer, also looks for frequency of clear nights and dark skies first. "It doesn't do you any good if it's a great site two nights of the year," he comments.

But it's easier to name these crucial factors than to measure them, a situation that makes site selection a problematic process. The published technical literature on site selection is relatively sparse, and astronomers freely admit that much of the traditional wisdom about site selection is as much folklore as fact. "As far as I know, there has never been a really major effort to research how to select sites," Jones says. Gehrz, who is considered an authority on the subject, thanks in part to his experience in the construction of the 2.3-meter Wyoming Infrared Telescope, says, "We understand little quantitatively about sites. The measurements we can best make and the factors we know the most about are sky brightness and cloud cover."

Much of the founding research on site selection is the work of Merle F. Walker of Lick Observatory. About twenty years ago, Walker conducted a two-year survey of several potential sites in California; more recently, he has turned his attention to examining observing conditions at existing observatory sites, especially Mauna Kea.

Summarizing the results of his California site survey in a 1970 paper, Walker stated that "the best astronomical seeing occurs very near the coast, where one has an undisturbed air flow off the ocean and where the cold ocean current lowers the height of the inversion layer."

But do coastal sites really offer better seeing conditions? Many astronomers aren't sure whether there is any inherent difference in the quality of seeing at coastal, oceanic, or inland sites. For example, Gehrz states, "We'd never have put a telescope in Wyoming if we had believed the folklore, which said there was no way to get good seeing, exceptionally clear skies, and low water vapor in the heart of the continent." He believes that "the best wisdom we have is that seeing is better at higher altitudes, and that since atmospheric turbulence is associated with bad seeing, you want your telescope located where the air flow is laminar, that is, smooth. Both these seem to be borne out by all site surveys."

In March 1986, the LTC began measurements of the seeing at Capilla Peak, South Baldy, and Sac Peak. The group is using Walker-style telescopes to measure star trails and the separation of double stars. They will conduct a series of test measurements at all three sites over the course of a year or more. That's much less than ideal, however. To obtain the best possible measurements of seeing would require "a good telescope and several years of observations," says Jones. But even if you've obtained good measurements of seeing over a period of time, it's still hard to evaluate the long-term quality of the site. The basic difficulty is that atmospheric turbulence and its relation to what astronomers call "seeing" — the sharpness and stability of images — is not well understood, and a solid theoretical basis is lacking.

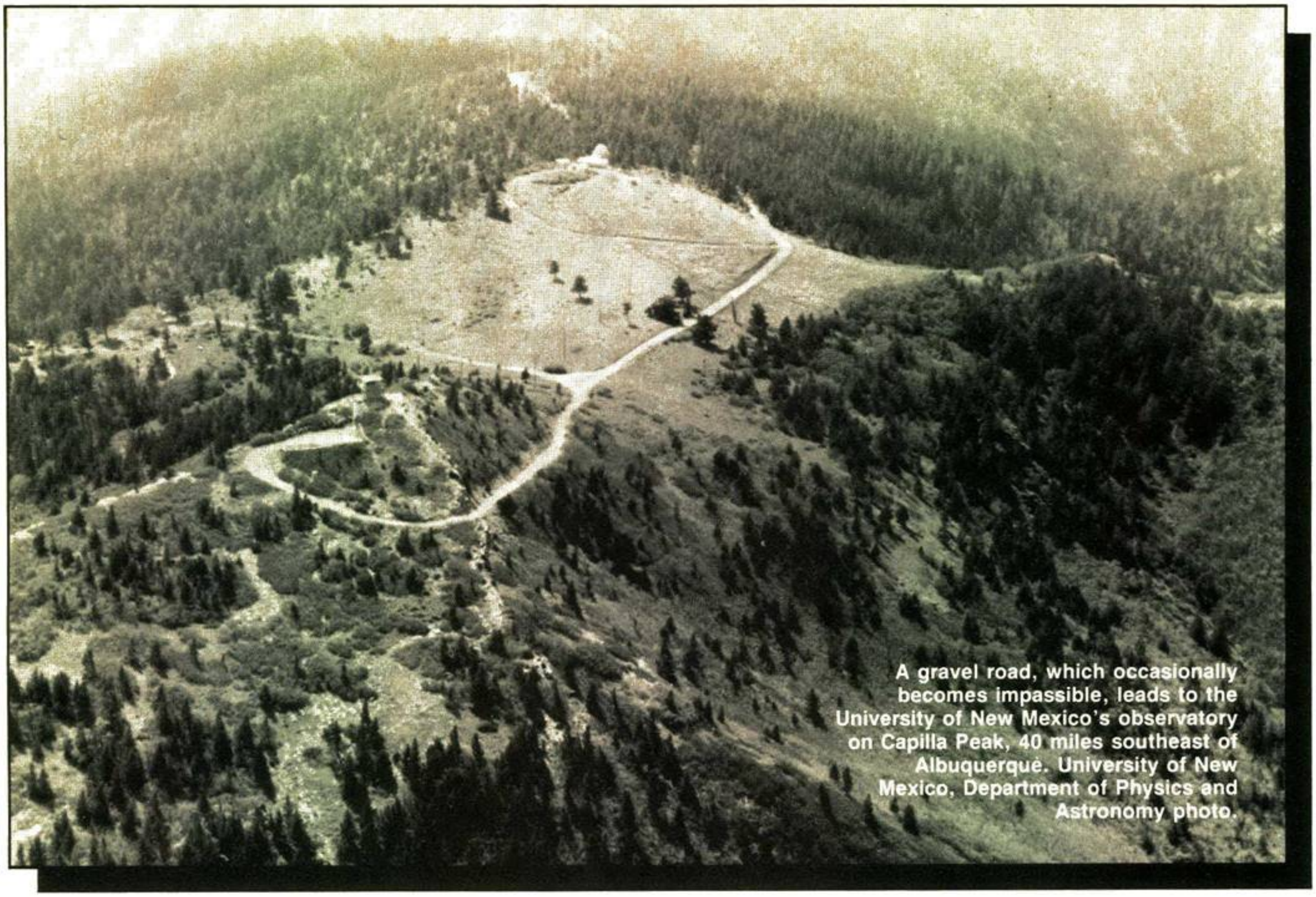
The Lifetime of an Observatory

Sky brightness is considerably easier to evaluate than seeing. Jones calls it "a hard measurement you can rely on." But it's also a condition that's likely to change with time, as several major observatories have already found out. Sky brightness was an important factor in the Carnegie Institution's decision to shut down its 100-inch telescope on Mt. Wilson last year. The American Astronomical Society estimates that light pollution has increased fortyfold in the past two decades.

Sky brightness measurements could prove to be the decisive factor in the LTC's choice of a site because the group wants the planned observatory to enjoy a long lifespan. "We're looking for sites that will take us well into the next century," says Gehrz.

To measure sky brightness at the New Mexico peaks, the group is using optical spectrophotometers equipped with filters to measure brightness at key wavelengths. A nine-month series of nighttime sky-brightness measurements has already been conducted at Sacramento Peak Observatory. The results of that study, published in 1979 by Timothy J. Schneeberger and others, revealed an average zenith sky brightness of about 22 magnitudes per square arcsecond — a considerably darker sky than Kitt Peak's. According to Schneeberger, "The darkest nights at Sacramento Peak compare favorably to measurements made at other dark sky sites."

"My real concern is clear nights, at all three sites, during the summer monsoon season," says Humphreys. Capilla Peak, South Baldy, and Sac Peak all receive most of their annual precipitation during late summer. Monitoring gives a good indication of the number of clear



A gravel road, which occasionally becomes impassible, leads to the University of New Mexico's observatory on Capilla Peak, 40 miles southeast of Albuquerque. University of New Mexico, Department of Physics and Astronomy photo.

nights per year at a site as well as revealing seasonal patterns. But historical weather records provide a valuable addition to data gleaned from monitoring. This is another advantage of choosing a developed site.

"The best sources of all are logs at developed sites," says Gehrz. Although the solar observatory at Sac Peak has more detailed records of daytime than of nighttime conditions, two separate sets of data exist on cloud cover at the observatory. According to Jacques M. Beckers, who analyzed and published the data with several co-authors, the records show that Sacramento Peak Observatory, "being a high mountain site, has a fair amount of cloud cover." For nighttime observing it has about a 70 percent probability of seeing any object at any time and about a 35 percent probability of completely clear nights. Langmuir Laboratory on South Baldy has kept a variety of weather records for several decades, including data on precipitation, air temperature, wind, and thunderstorms.

Monitoring, however, is the only way to evaluate conditions related to cloud cover because historical records are unlikely to include data on how rapidly clearing occurs above a site. Unfortunately for observers seeking a site, the records that exist at developed sites generally haven't been kept for the purpose of facilitating site selection.

Annual precipitation can give a rough indication of cloud cover at a mountain site. Sacramento Peak, for example, receives about 26 inches. That's a bit more than at either South Baldy in the Magdalena Mountains or Capilla Peak in the Manzanos. Because of its location southeast of the Magdalenas and Manzanos, Sac Peak may receive more of the effects of the flow of moist air from the Gulf of Mexico. On the other hand, at least one astronomer who knows Sac Peak well says that cloud cover on the peak comes mainly from local conditions.

There is one simple rule of thumb for estimating the dryness of the air over a site: the higher the site, the lower the water vapor because there is less atmosphere above the site. Like cloud cover, atmospheric water vapor varies seasonally, but it can be fairly accurately measured with meters that measure the amount of vapor in line to the Sun or Moon.

Comparison Shopping for a Site

Gehrz is quick to point out that the consortium is really conducting a site comparison and not a site survey. "We're not setting up survey instruments to test all these factors regularly over a long period of time," he points out, since exhaustive site surveys are expensive as well as time consuming. Walker's California site survey, generally considered a model, was conducted over a two-year period and cost $80,000 in 1960 dollars.

The cost of extensive site surveys may not be justified because of the difficulty of accurately measuring such complex characteristics as seeing. In Gehrz's view, "The best thing to do is to examine the sites periodically and to take into account what we've learned from other sites, and so make a comparison among them." The process is like comparison shopping with your consumer buying guide in hand.

The sites under consideration "have mostly been suggested to us by people who are already there," Humphreys points out. The purpose of the site comparison, then, is to discover any adverse factors at a particular site. Judicious sampling should allow the group to observe and measure the best and worst observing conditions on each peak.

The astronomers who have jolted up the unpaved road to South Baldy in a caravan of trucks and four-wheel-drive vehicles wonder why Baldy is bald. No one present knows for sure. Is the bare ridge, covered only by a scruff of low-growing vegetation, the product of winds sweeping over the ridge? Is the backbone of the ridge simply too rocky for trees to flourish?

In any case, South Baldy offers a spectacular view, unobscured by trees. "I can see it now," crows one of the group, "a resort lodge with big picture windows. . ."

To the west, the twenty-seven giant dishes of the Very Large Array radio telescope make a decorative pattern against the brown plain. Langmuir Laboratory, a major center for thunderstorm research, is located on the ridge at an altitude of 10,631 feet along with the Joint Observatory for Cometary Research and the supernova-search telescope. South Baldy Peak rears up a couple of hundred feet above the ridge.

From this height, several thousand feet above the plain, you can clearly see how sparsely settled this part of the country really is. Off to the north is the village of Magdalena; 17 miles to the northeast is Socorro. At night, the glow of Albuquerque would also be visible. How bright would it be? "You can see a faint glow if the weather is right," says one of the local astronomers. "In fact," he continues, "it's been said that the brightest object visible from South Baldy is the airport beacon at Truth or Consequences, about 90 miles south."

The group splits up, several following a local guide up to the summit, the rest strolling over to West Knoll, which juts out from the main ridge. "The folklore would say this is where you should build," one of the visitors comments. Standing on West Knoll and looking out to the vast desert beyond, one astronomer opines, "I have a feeling this is a really dark site. For the next hundred years, there won't be any problem in that direction."

Like Capilla Peak, South Baldy is part of the Cibola National Forest. (Whatever the cause of its baldness, it's a local effect, since surrounding mountains are forested.) The National Forest Service has designated the land along the ridge where the existing facilities are located as a scientific preserve.

"Say, are there bears up here?" someone asks suddenly, perhaps envisioning an observer accosted by a grizzly en route from the dormitory to the dome. "Don't worry," comes the reassuring reply, "the last time a bear was shot up here was sometime around 1967. Deer and turkey are the major game animals."

By the time the October sun is overhead and the air has warmed, the group is headed back down the mountain to Socorro where they'll regroup and head southeast to Sac Peak, the third and final stop on the tour.

The LTC would like to see its telescope operating in the next five or six years. The telescope, an equatorial Cassegrain with an f/2 primary, is being designed by Frank Melsheimer, who also designed the new Michigan-MIT-Dartmouth telescope at Kitt Peak, Arizona. At 18 tons, it will be a comparatively lightweight instrument featuring two interchangeable secondary mirrors: a standard f/5 and an f/20 optimized for infrared work.

If the proposed three telescopes are built, it will be possible to fit each with different instruments for simultaneous observations of the same object at different wavelengths. Equipped with identical instrumentation, the telescopes could be used for "superresolution," integrating simultaneous observations of a single object using sophisticated image-processing techniques to simulate a larger aperture.

"Eventually," Humphreys adds, "you might be able to do optical and infrared interferometry. No one has succeeded in doing this yet, although a lot of people are talking about it."

The Need for Ground-Based Scopes

But why build a telescope now, in an era of flat-bellied, tight-belted scientific budgets? And why build a new ground-based observatory at all with the Hubble Space Telescope ready for launch? Humphreys, who as prime mover has already invested considerable time and energy in the project, sees several compelling reasons.

First is the opportunity to undertake the kinds of large-scale, long-term observing programs that can't be done at national observatories. These observatories have only so much telescope time to allot and competiton is intense. Generally, a non-staff user will be granted a few nights or a week per year at most on a large telescope at a national observatory. As Humphreys points out, "This makes it difficult to do projects that need lots of observations of lots of objects.

"For example, about ten years ago I was doing spectroscopy and photometry of individual stars in nearby galaxies. If I'd had my own scope, I might have had one week a month, so bad weather and instrument problems would not have been so important. But if you only get a few nights a year and some of those are lost to weather and instrument problems, you just can't do that type of project."

Laura Patricia Bautz, director of the Astronomical Sciences Division of the National Science Foundation, also recognizes the extent to which national observatories are oversubscribed. "The allocation committees try to allow for some large-scale projects, but there's more science being done right now than can be handled with the existing observatories," she says.

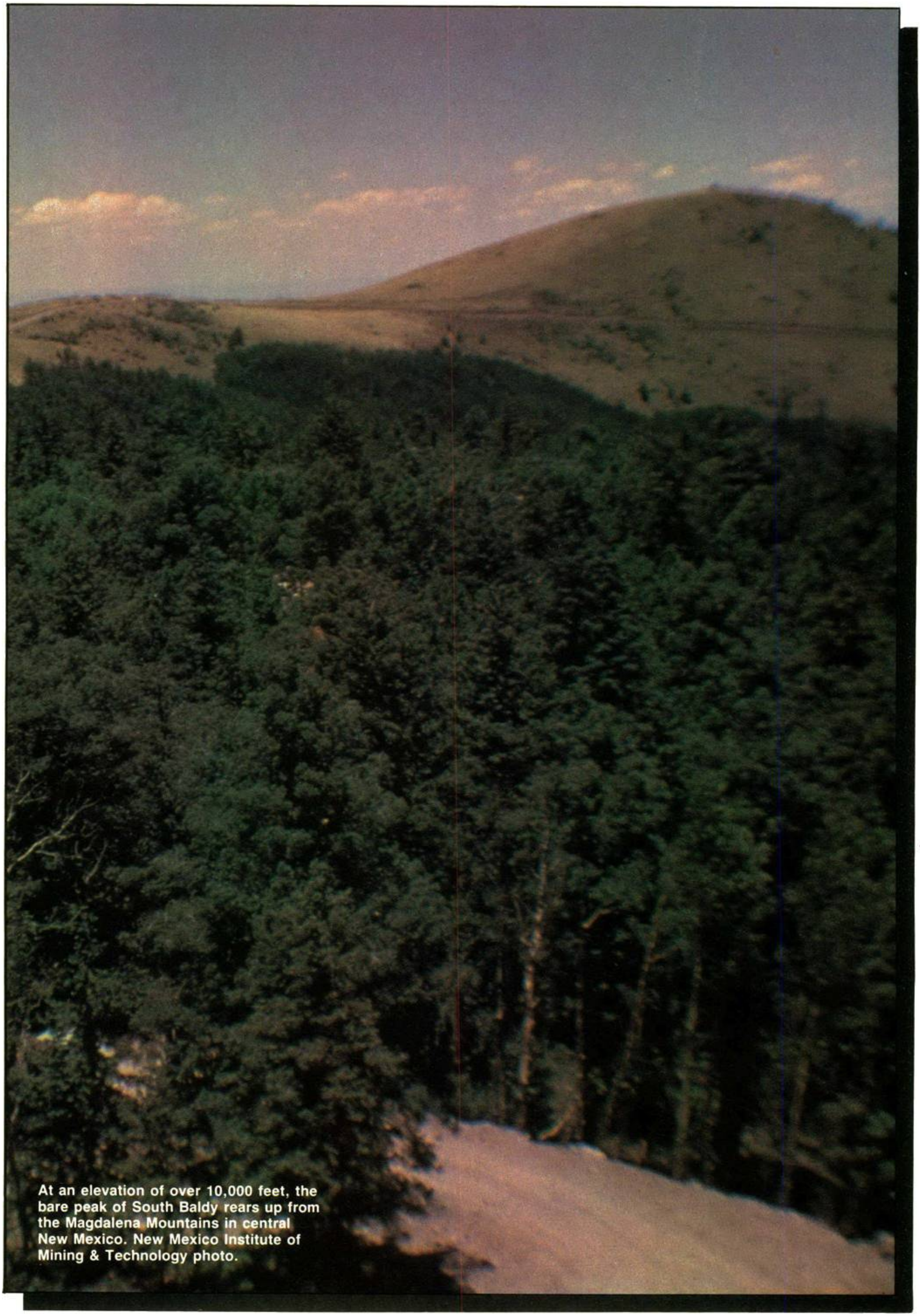
Also, as any amateur astronomer knows, responding to new discoveries is easier when you have your own telescope. That applies to professionals, too. Investigating new discoveries and temporal events virtually requires the dedication of a facility.

Use of ground-based telescopes is expected to increase once the Hubble Space Telescope begins routine observations and astronomers conduct preparatory and follow-up observations to Space Telescope projects. A current estimate is that each hour of Space Telescope time will require more than twenty hours of ground-based follow-up.

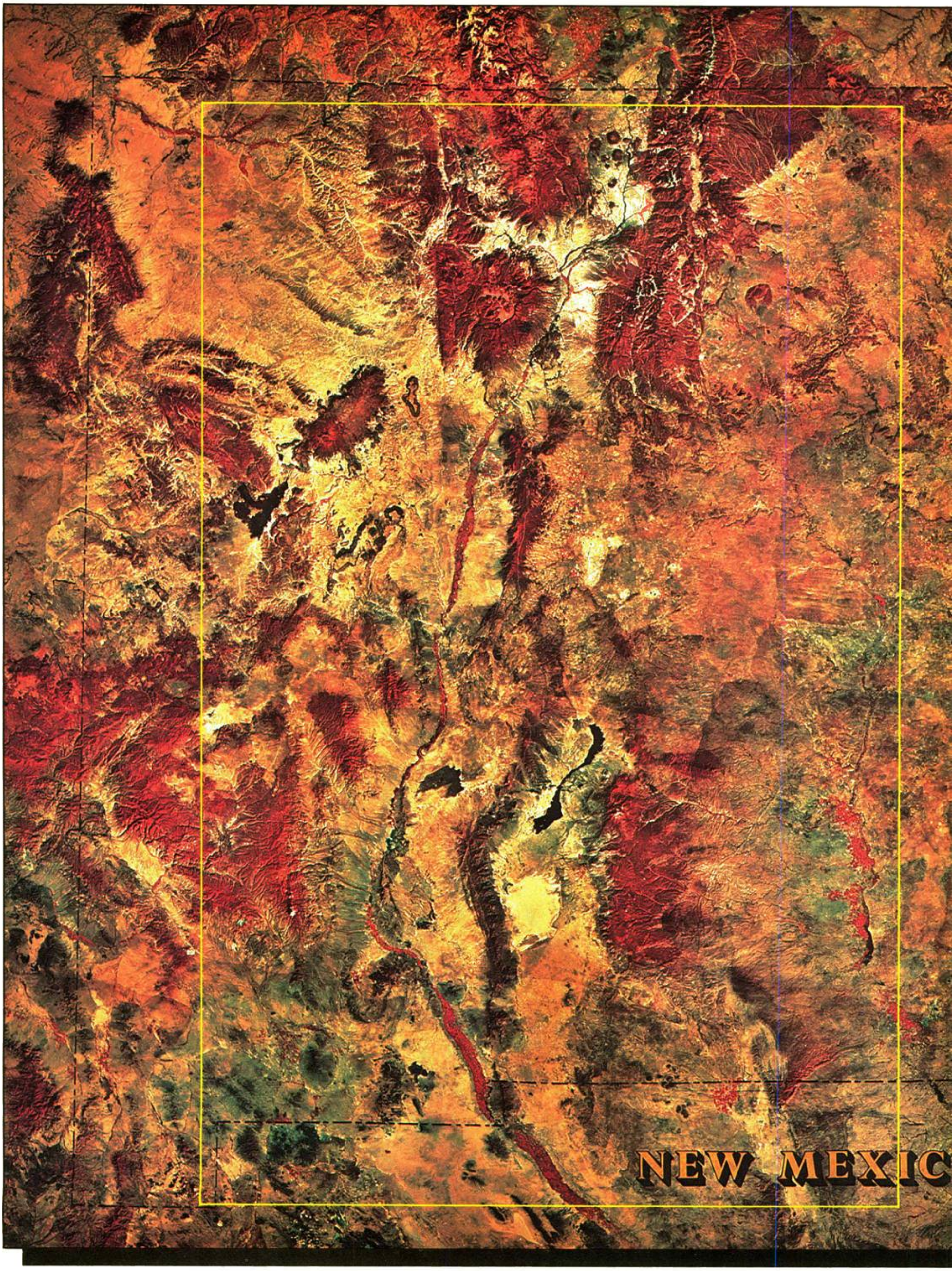
Finally, building a telescope is particularly appealing now because in recent years the cost of building large telescopes has actually gone down. Says Humphreys, "The four-meter telescope at Kitt Peak, which was built in the early 1970s, cost $10 million in 1970 dollars. Today, that would be $25 or $30 million. Yet we're talking about building a similar aperture telescope for the same dollar amount as Kitt Peak. That represents a real decrease."

The lower cost is due primarily to developments in telescope design. Today's thin mirrors and honeycomb mirrors are lighter than mirrors used to be. In addition, the move toward faster primaries means that a telescope of the same aperture can be lighter and shorter than would have been possible ten years ago. In turn, the telescope enclosure can be smaller and cheaper.

While the site comparison proceeds, Humphreys and other LTC members will begin raising money for the first

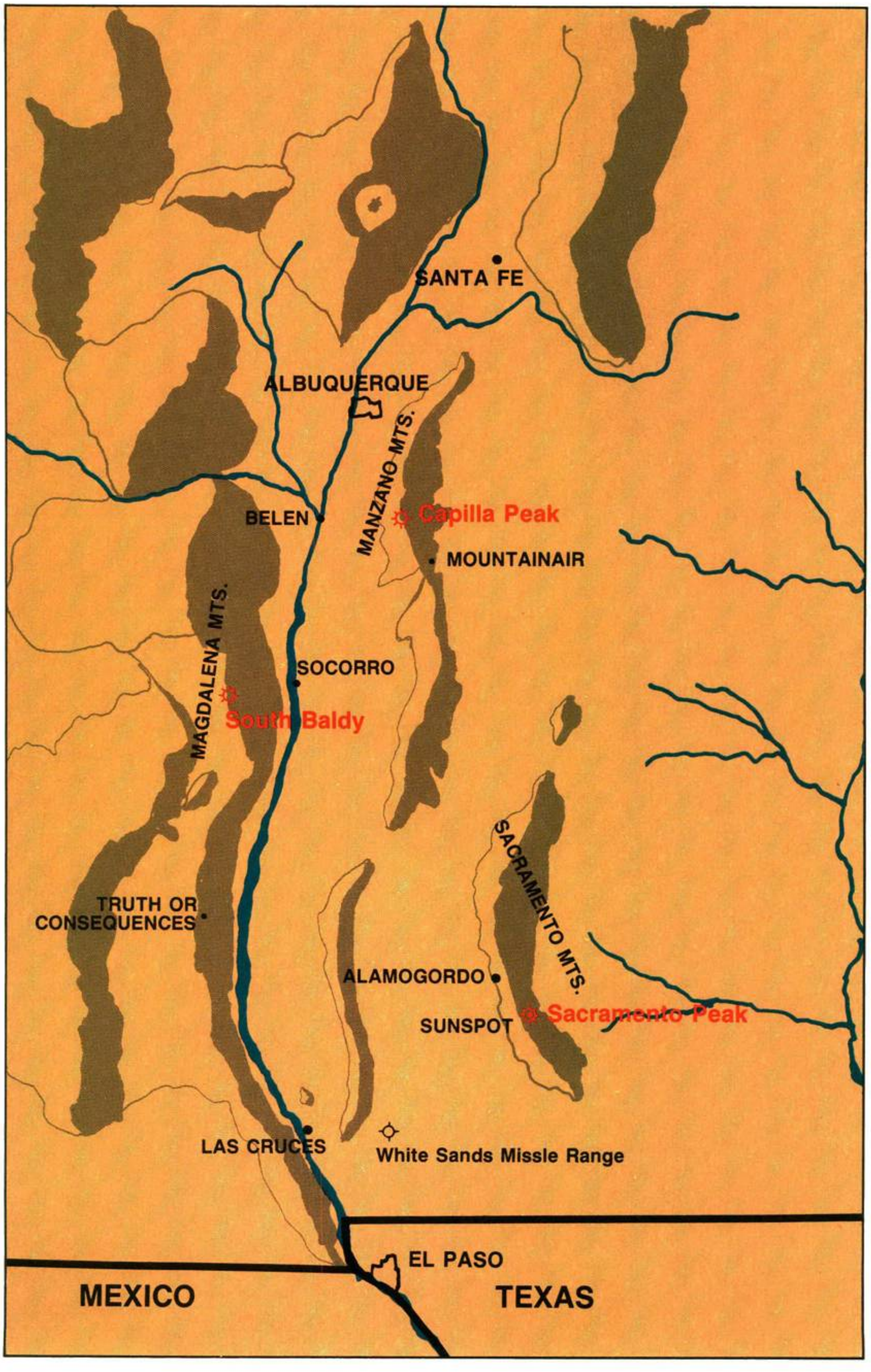


At an elevation of over 10,000 feet, the bare peak of South Baldy rears up from the Magdalena Mountains in central New Mexico. New Mexico Institute of Mining & Technology photo.


NEW MEXIC

Astronomical Real Estate

The State of New Mexico, already the site of many observatories, may get one more if the Large Telescope Consortium decides to build their 3.5-meter telescope there. The three sites currently under consideration — Capilla Peak, South Baldy, and Sacramento Peak — are shown on the map below. NASA photo.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Capilla Peak
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ALAMOGORDO
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Sacramento Peak
LAS CRUCES
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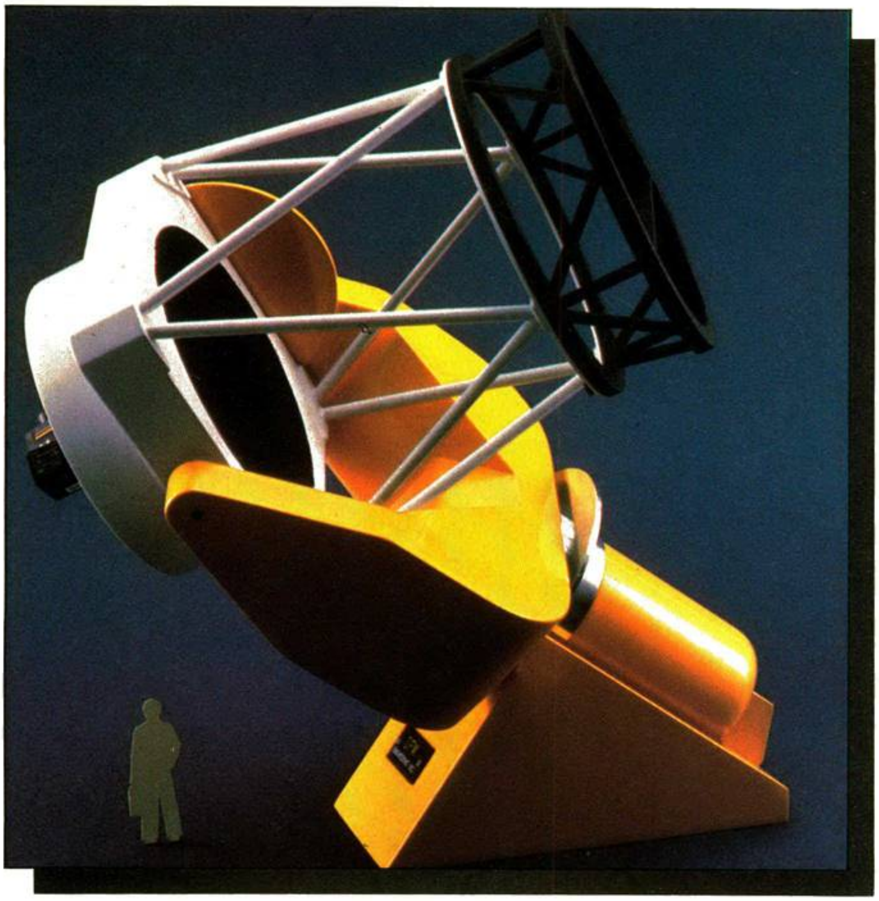
TEXAS



The cost of the 3.5-meter telescope that the Large Telescope Consortium hopes to have operating by 1992 would be a relative bargain at $10 million. University of Minnesota photo.

step toward construction of their telescope: ordering a mirror blank. At a cost of about $1 million, and with a lead time of eighteen months between ordering and delivery, the primary mirror is not only expensive but also "the biggest time sink," Humphreys says.

The Trouble With Trees

A wide, paved road leads up to Sacramento Peak Observatory, but at the turnoff to Apache Point the group meets a work crew whose foreman says, "Sorry, the road is closed due to construction." Explanation, however, leads to a compromise. "Come back in half an hour and you'll be able to get through," the group is told.

It's late afternoon by the time they arrive at the site, which is actually two sites: Site B, the location chosen by the Apache Point consortium for their 3.5-meter telescope, and Site A on an adjacent ridge. After the long drive from Socorro, everyone is glad to stretch their legs and take a walk through the trees that thickly cover the site. It's a scenic spot, green and refreshing. "But all these trees mean water," someone points out. And astronomers aren't the only creatures to appreciate a stroll through the forest. The group soon discovers deposits that turn out to be the biggest cow pies any of them has ever seen.

Located on a ridge that juts out to the west, Apache Point is the kind of formation that should cause air flow around the peninsula and up over the ridge, producing very little turbulence and improving the seeing. Like South Baldy, Apache Point has a steep drop-off, which is generally considered an advantage because of the smooth air flow produced by presenting a blunt face to the wind.

Do trees have any affect on seeing? Most astronomers believe they do, but they're not so sure about what the effect actually is. Some believe that trees cause turbulence. As one astronomer puts it, "Whenever you hear it, you'll also see it." But another points out that "the claim used to be that trees settled the seeing down." Gehrz says, "I'd guess that for the best seeing you probably wouldn't want a whole lot of trees. The half dozen best sites I know of are not heavily treed. But this isn't proven."

One of the chief attractions of Sac Peak for the Apache Point consortium is the presence of the National Solar Observatory, which has a library, a machine shop, and good roads. But as one of the astronomers on the site visit says somewhat wistfully, "I liked the feeling of isolation at South Baldy. I believe observatories ought to be isolated."

As the sun is setting, the group splits up. Several astronomers are spending the night in Sunspot to get an idea of nighttime conditions on the mountain. Others, constrained by tight schedules, are driving back to Albuquerque this evening. By the time they reach the foot of the mountain, night has fallen. The lights of nearby Alamagordo twinkle brightly against the surrounding darkness.

In the car driving away and later in the visitors' quarters at Sunspot, the discussions continue. Baldy has plenty of room and a good configuration. . . Capilla is attached to the University of New Mexico. . . Sac Peak is well developed. . . Capilla is easy to reach from Albuquerque. . . Sunspot would be a pleasant place for staff to live. . . Baldy is higher and therefore drier.

Speculation will turn to decision once the site testing, which is still underway, is completed.

Lys Ann Shore is a freelance writer and editor in Socorro, New Mexico. She is the former managing editor of Association Management *magazine in Washington, D.C.*

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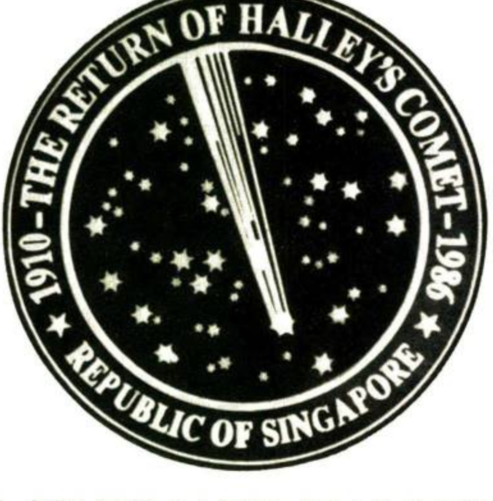

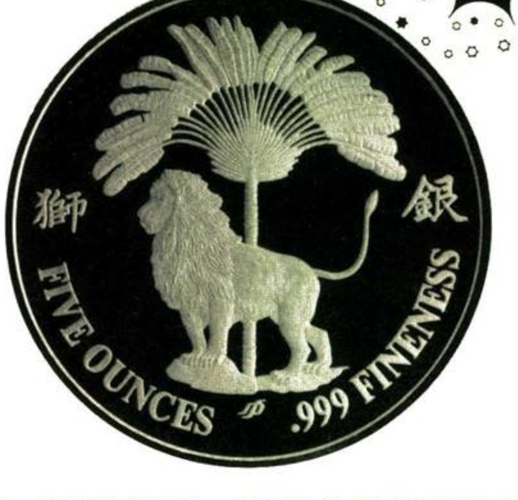

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ASTRONOMY Forum

My Most Memorable Comets

Comets have always played a vital role in adding zest and interest to the skies of my memory.

As a near-sighted, nine-year-old boy growing up on a 440-acre farm in Glendale, Florida, my main interest was the abundance of fossils that I found on our farm. Without glasses, the stars appeared to me as big blurs.

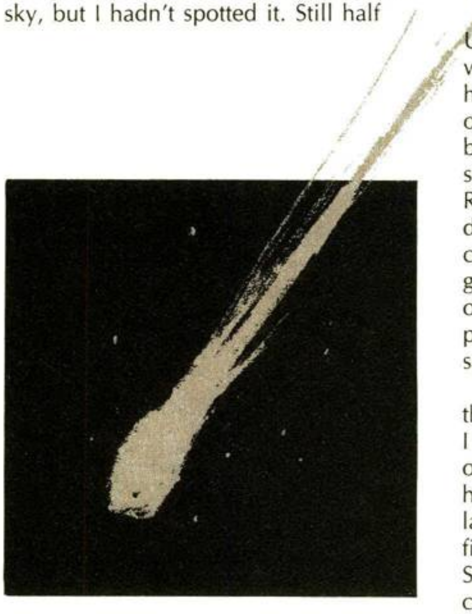
We were combining oats on a hot, dry August day in 1957 — a job that fills your underwear with itchy oat husks that scratch for months. I rode the combine, bagging oats all day as we rushed to get the crop in before rains rotted it in the fields. As evening approached, I walked in front of the pickup, dragging oat bags into piles to speed up their collection.

Exhausted, I collapsed on the last pile of bags and gazed up at the western sky as darkness fell. There was an object that obviously wasn't a star! It had a tail but, unlike the swift meteors I was familiar with, it did not appear to move against the star patterns. It was a comet, I decided with excitement, and I noted that its tail pointed eastward away from the Sun.

Later I learned that it was the widely observed Comet Mrkos, designated 1957e. The comet was easily visible with the naked eye for weeks, and I kept up with it as it moved away from the Earth and Sun and faded from view. How I wished for a telescope so I could follow it longer. My fascination with the comet inspired deeper reading into astronomy. My parents supported my interest with a gift of a 2.5-inch Gilbert reflector that Christmas.

Over the next few years I acquired binoculars, a 6-inch Newtonian, and finally a 10-inch Starliner Newtonian. I helped Rand Baldwin organize the Walton County Astronomy Club (WCAC). With our parents' support, the group grew to over 40 junior members in the county schools by 1965.

On the morning of October 28, 1965, I planned to observe Jupiter at about 3:30 a.m. and hopefully catch a glimpse of Comet Ikeya-Seki (1965f). I knew from news reports that the comet had put on a fine show in the daytime sky, but I hadn't spotted it. Still half asleep, I pulled the dust covers off my 6-inch, which was stored on our front porch, and aligned it with Polaris. Then, glancing eastward to admire the clear sky and note Jupiter's position, I saw what appeared to be a searchlight beam sweeping south of the bright planet. There weren't any airports east of our house, I thought. It was over 40 degrees long, too. Could it be? Yes, it was! That was the tail of Comet Ikeya-Seki!



I ran inside the house, woke up my parents, and quickly called a dozen of the most dedicated WCAC members. The spectacle was so impressive that no one complained at school the next day about the early-morning wake-up call. Later in the year, our astronomy group organized a comet gaze at the school baseball field that attracted over fifty comet watchers — a great turnout for a small town like DeFuniak Springs, Florida. To this day, the view of that long, glorious streamer of light in the sky remains one of my most memorable images.

The following year, I went to the University of Florida to continue my work in astronomy. Early in 1970, we heard that Comet Bennett would put on a good show, rising in the east before sunrise. It would be too low to spot from the student observatory, so Rand Baldwin and I persuaded our dorm mates to go on an early-morning comet ride to find a clear sky. We did get fine naked-eye and binocular views of the bright comet rising over the pines. Alas, exams were due so I only saw Comet Bennett once.

By 1973, I was teaching school in the small rural town of Paxton, Florida. I tried to kindle an interest in astronomy among my students. When the hoopla over Comet Kohoutek began in late 1973, I photographed it with a five-minute tracked exposure near Spica. My photo revealed only a faint coma and short spike of a tail, but we still expected this "comet of the century," which made the cover of *Time* magazine, to do great things.

In January 1974, I organized a comet gaze to view Comet Kohoutek. There was little light pollution and we had a nice view of the much-publicized comet, which I photographed with my 35mm Minolta. Its tail was about 20 degrees long in my 7x50 binoculars. For most people, this comet was a notable astronomical failure that did not get nearly as bright as optimistically predicted. With dark skies, however, my students were not as disappointed as were many city

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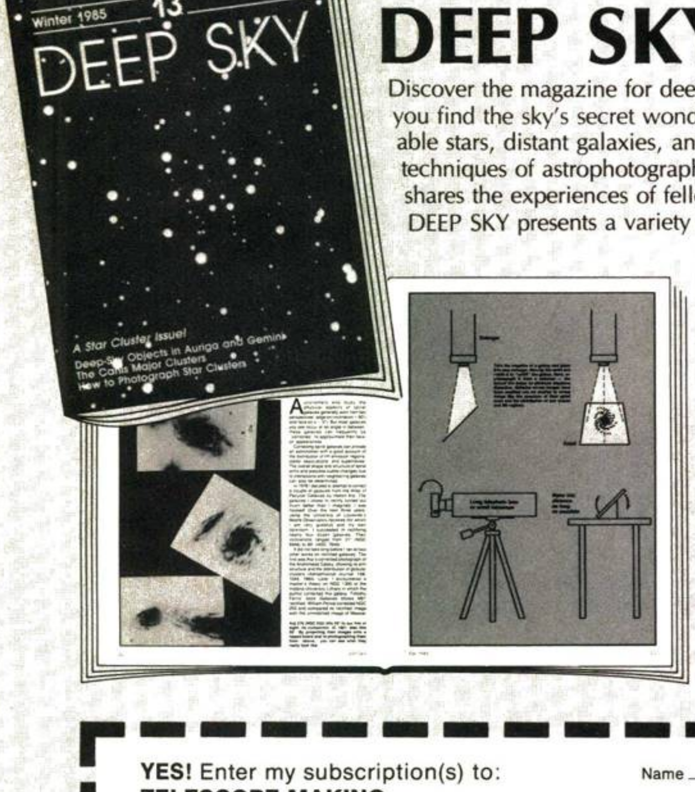
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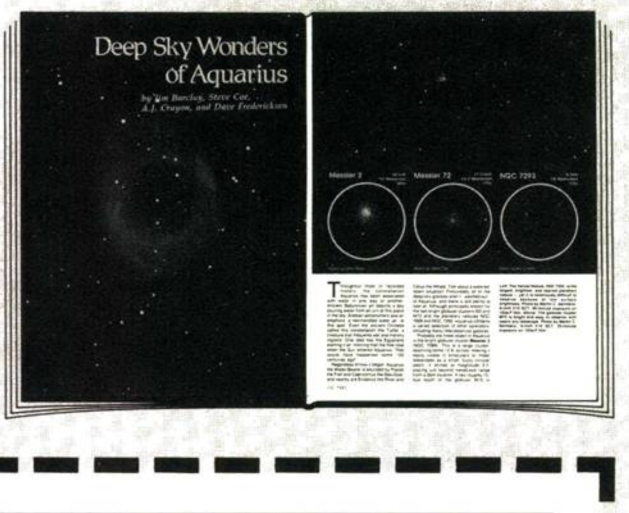
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dwellers who failed to spot the comet at all.

The most beautiful comet of my life passed almost unnoticed by the press and the public two years later. According to my IAU cards, Comet West (1976f) was coming from behind the Sun in early March 1976. By now I was living in light-polluted Pensacola and working as an astronomy instructor at Pensacola Junior College. I had scouted out dark-sky sites nearby and rose every morning during the first week of March to view Comet West from the bluffs overlooking the Escambia River. But every morning it was either foggy, cloudy, or rainy. Dampened frequently, lacking sleep, and almost down with pneumonia, I was elated when the clouds at last parted on March 8 to reveal the fine fan-shaped tail of the 2nd-magnitude comet in the eastern twilight. Using only a camera, fast film, and a tripod with cable release, I got several dramatic shots of this beautiful comet before it faded into the twilight.

My next memorable comet was IRAS-Araki-Alcock (1983e), an Earth-grazing comet that passed closer to us than any comet since 1770. This one I shared with my wife, Merry Edenton Wooten, and our two-year-old son, Michael. We were delighted when Escambia Amateur Astronomer's Association member Buddy Welker, himself a dedicated comet observer, notified us that the newly-found comet could be found in northern Draco in early May. With EAAA member Rick Little, we observed the comet in binoculars and copier lens telescopes that I had built.

Comet IRAS-Araki-Alcock appeared as a circular fuzzball, but we anticipated it brightening to easy naked-eye visibility as it moved through the dippers. But our usual cloudy Florida weather moved in and by May 11 the comet was heading through Cancer and into the Sun's glare without giving us a view of it at its best.

It was still cloudy on the afternoon of May 11, but as Michael and I came out of the grocery store about dusk, he said, "Look, Daddy, Venus!" (Not bad for a two-year-old!) He was right; the clouds were parting a little. We rushed home and grabbed Merry, the binoculars, a cable release, a tripod, the Minolta, and a roll of Kodacolor 400 film. No time for the C8, clock drive, Schmidt camera, etc. — this was *astronomy on the run*!

We drove east across the Escambia River to a dark rest area near Avalon Beach and quickly set up for unguided snapshots. Merry soon spotted Comet IRAS-Araki-Alcock in the west; it was the brightest object between Gemini's Castor and Pollux and Leo's Regulus. The comet was just below and to the left of the famed Beehive Cluster (M44) in Cancer and was visually brighter than the cluster but otherwise comparable to it in size and appearance. Both looked about two degrees in diameter; the comet had no discernible tail.

With binoculars, the real nature of the two objects was striking. M44 resolved nicely into the best of binocular clusters and the comet's coma remained fuzzy and greenish. Its motion was apparent after a few minutes of observing.

We called Jack Hixon of the EAAA, who was then a night disc jockey for WCOA radio, and described the comet's position and brightness. Jack broadcast this information over the air and then ran outside at his next break to see for himself. Unfortunately, clouds were already rolling in over Pensacola. We too were soon clouded out, but I will always be thankful for the hour of broken clouds and my son's watchfulness.

What do memories of past comets have to do with observing Halley and comets in general? First, always expect the unexpected. Kohoutek was a dud, but Ikeya-Seki, West, and IRAS-Araki-Alcock were better than predicted.

I know many of you will be disappointed with Comet Halley. Like you, I heard accounts from the older folks of how bright it was in 1910. (Incidentally, some of those memories are based on an even brighter comet — the Great January Comet — seen earlier in the same year.) I heard glowing accounts from my 105-year-old great aunt, Christian Wooten, who saw Halley four times closer to the Earth than it is now and much higher in the sky as well. She also viewed it through clear, unpolluted skies before the days of electric lighting and other atmospheric pollution.

Comets have been a lot of fun for me. They add a lot of zest to amateur astronomy, especially through the challenge of finding your own. If Halley doesn't live up to your expectations, don't give up and sell your two-thousand dollar 8-inch scope for two hundred dollars. Hang onto it — there's always Jupiter, the Moon, Saturn, galaxies and nebulae, double stars, and the promise of a real "Comet of the Century." That comet may be approaching us right now, just waiting for someone like you to find it. What a way to go down in the history books!

Wayne Wooten
Pensacola, FL

Buying a Telescope for the Kid

As a professional astronomer and university professor, I have been asked by many parents what type of telescope to buy for their children. Before making any recommendations, I always ask four questions:

1. How deeply do you want to get into astronomy, or how interested is your child? (As a friend of mine says about electric trains, "Which kid is it for, you or the young one?")
2. What sort of objects do you want to observe?
3. Do you want to look at these objects, photograph them, or do something more advanced?
4. How much are you willing to spend? This will depend not only on your pocketbook but also on how well the budding astronomer has cared for special things in the past.

As any reader of this and other science-oriented magazines is aware from even a cursory glance at the ads, telescopes come in a wide range of price and performance levels. In general, I advise against toy and department store telescopes, since they are generally of poor quality and the sales clerks usually know little about them. Also, most of these telescopes do not take standard 1¼-inch accessories, so they cannot grow as the user gains experience and broader interests.

Recently, my five-year-old son added astronomy to his wide range of interests. The signal that he was serious came in the form of a direct request for his very own personal telescope. He told his mother that we could occasionally look through the telescope at interesting objects, but that he would operate the instrument. Suddenly I was the one confronted with the question, "Which telescope?" My own money was being put on the line.

I decided to apply the same telescope-buying criteria to myself that I had always recommended to others. To determine the level of my son's interest, I told him he would have to learn to identify and point out five prominent constellations. I knew he already could identify many types of astronomical objects because I had been giving him questions from my introductory physical science classes since he was about three. I told him he would also have to point out any bright planets in the sky and identify them. He demanded to be taken out that very night and every clear night for the next week to be given an introduction to the sky. Pop wasn't going to get off so easily!

Within the week, he could identify

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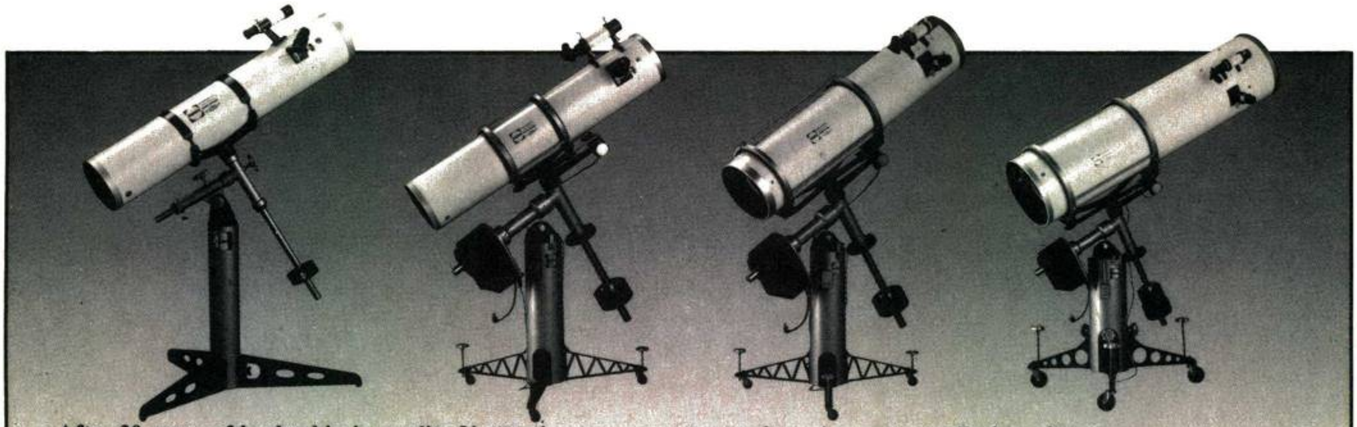

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Orion, the Big Dipper, Cassiopeia, Taurus, Canis Major, Canis Minor, the Little Dipper, and Auriga. Venus was bright and easy; Mars was a bit harder to see. The other planets came up after his official bedtime, although he was eager to find them. By the end of the month, it was obvious that I either had to get the telescope or boost the prerequisites unreasonably.

When I asked my budding astronomer what sort of objects he wanted to observe and whether he wanted to look at these objects, photograph them, or do something more advanced, I got the same answer both times: "Everything."

This made things very difficult since not every telescope does everything equally well. There are rich-field telescopes (relatively inexpensive), Dobsonians (good for looking at fainter objects), refractors on equatorial mounts with and without drives (nice for looking at planets and double stars), Newtonian and Cassegrain reflectors on equatorial mounts with and without drives (suitable for astrophotography), and Schmidt-Cassegrain designs mostly with drives (portable, nice for both observing and photography, but much more expensive).

I usually advise people to get a good telescope with a drive, if they can afford it. A hard-to-use telescope will probably cause a rapid loss of interest. Good telescopes with equatorial mounts and clock drives are fairly easy for the beginner to use. A good telescope is also easier to sell if the user loses interest or if the interest deepens and a better telescope is desired. I have also suggested a good pair of 7x35 or 7x50 binoculars, if the child's interest does not seem too deep. However, binoculars suffer one major deficiency as an astronomical instrument: they are not adequate for viewing the planets in detail.

In searching for my son's telescope, I now perused the ads and catalogues with a heightened interest. To my dismay, I saw that the prices of the telescopes that came close to meeting my criteria were too expensive to give to a five-year-old.

Thus, my fourth criterion — how much are you willing to spend? — caused me to consider the very thing I had advised so strongly against: going to the department and toy stores. I was confronted with a small selection of 2- to 3-inch refractors that had plastic tubes and pop bottle lenses, and reflectors with shaving mirrors, all mounted on tripods inadequate for supporting the one or two pounds of "instrument." A few had a hollow tube for a finderscope, and some of these were fitted with a couple of lenses to make a "3x finder." Several would have made good examples of distortion and aberration for my optics class. The price for these toys was in the $30 to $60 range — not too bad when skateboards can cost $150 or more.

To be completely fair, there were two reasonably high-quality brands that I found in several department stores, but they were high priced. In addition, the best-known major brand of refractor and two of the major Schmidt-Cassegrain lines are sold in department and camera stores. Unfortunately, my impression that sales clerks know very little about telescopes was confirmed. One clerk even referred to astronomy as astrology while looking at the label on the box.

So I was confronted with a dilemma. Should I buy a cheap toy that would prove disappointing in a short time or a good but much more expensive instrument? Some people (notably professional "educators") suggest that a child under ten or twelve won't notice the difference, that any telescope will do if a few stars can be seen. But I have met many under-ten-year-old's who could identify a dozen constellations easily and detail a star's life history. They are bright enough to know when a telescope doesn't work. Nothing can destroy a child's interest in astronomy more rapidly than an ineffective telescope or one that is too complex for him or her to use.

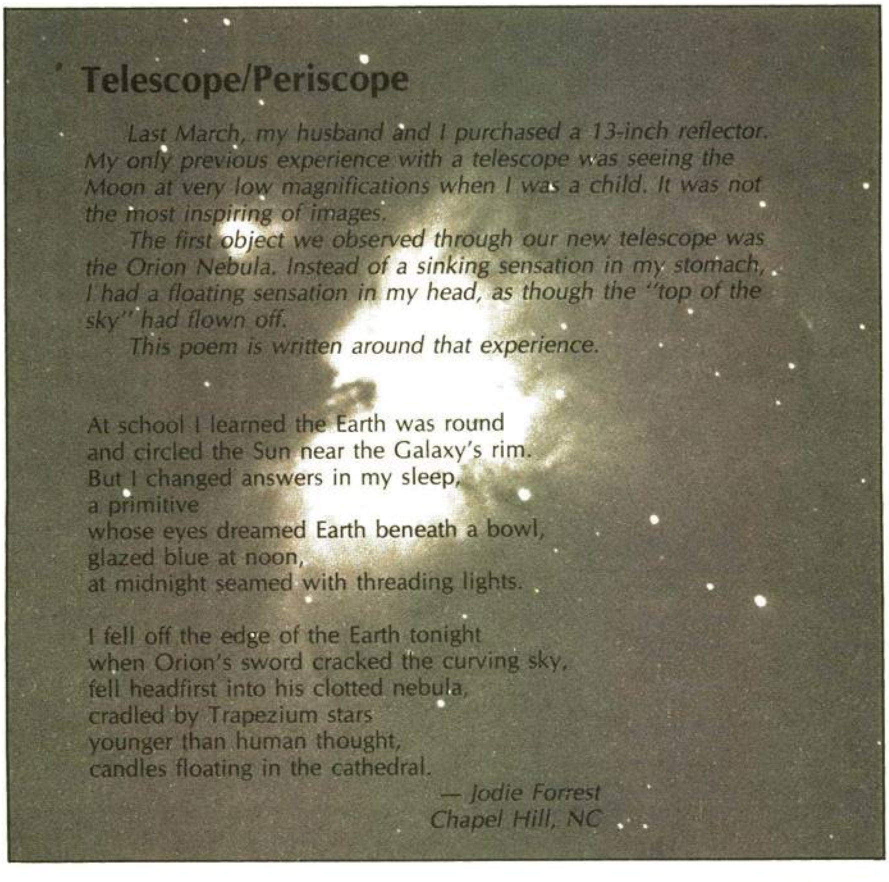
Luckily we have several good optical dealers nearby, so we set out on a series of visits to narrow down our options. I was pleased to discover that several manufacturers have brought out less expensive models ostensibly for viewing Comet Halley. They lack a few features, like clock drives and finderscopes, but these can be added easily at a later time. A very important point is that these telescopes take standard accessories.

After several visits, I sat down with my son to discuss the important features, advantages, and disadvantages of the various telescopes in terms he could understand (although Dad probably biased the discussion a bit). Such a discussion serves several purposes. First, it allows the child to feel that he or she has participated in the decision. Second, it helps to impress upon your daughter or son that the telescope is a special instrument to be taken care of, not a toy to knock around. Third, it allows you another assessment of your child's seriousness of interest.

In the end my son chose a small (125 millimeter) Schmidt-Newtonian with a 7x finder and a short tripod. In the weeks since the purchase, he has gone out on a number of nights to observe. He invites his parents most of the time and asks Pop's help in finding some clusters, double stars, and a nebula (Orion, of course).

Unfortunately, I overlooked one bad side effect of getting a telescope for the kid: he now has the perfect excuse for staying up well past his official bedtime.

— *William C. Straka*
Palo Alto, CA



Telescope/Periscope

Last March, my husband and I purchased a 13-inch reflector. My only previous experience with a telescope was seeing the Moon at very low magnifications when I was a child. It was not the most inspiring of images.

The first object we observed through our new telescope was the Orion Nebula. Instead of a sinking sensation in my stomach, I had a floating sensation in my head, as though the "top of the sky" had flown off.

This poem is written around that experience.

At school I learned the Earth was round
and circled the Sun near the Galaxy's rim.
But I changed answers in my sleep,
a primitive
whose eyes dreamed Earth beneath a bowl,
glazed blue at noon,
at midnight seamed with threading lights.

I fell off the edge of the Earth tonight
when Orion's sword cracked the curving sky,
fell headfirst into his clotted nebula,
cradled by Trapezium stars
younger than human thought,
candles floating in the cathedral.

— *Jodie Forrest*
Chapel Hill, NC

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ASTRONOMY
In Focus

Back-to-Back Messier Marathons

Sir / Phil Dombrowski's article ("One Night, Two Men, Three Sites, and 107 Messier Objects," Forum, February 1986) brought to mind my Messier Marathon adventure with Jim McGaha last year. Jim is a very experienced amateur astronomer and has served as chief observer for the Tucson Amateur Astronomy Association, Inc. (TAAA). From 1984 to 1985, the TAAA held an active campaign to encourage members to earn Messier certificates from the Astronomical League.

Jim set up a schedule of possible viewing nights and a Messier object search sequence. He practiced beforehand, finding the first ten objects that would set early in the evening at the start of the Marathon and the last ten objects that would rise just before dawn. Jim is also fortunate to have a roll-off roof observatory with two telescopes: a 16-inch f/4.5 and a 12½-inch f/5.

On the evening of March 23/24, 1985, Jim observed 109 out of 110 Messier objects. M-30 was lost in the early morning twilight and could not be seen with assurance, even in his 16-inch telescope.

The next day I got caught up in this Messier mania. I decided to go over to Jim's house the evening after his Marathon in order to expand my own Messier list. I had no intention of trying for all 110. I had to wake up Jim, who was trying to recover from being up the entire previous night.

At sundown we started. I was to observe with the 16-inch and Jim with the 12-inch. We each had to find an object on our own. Once sighted, it was then confirmed by the other observer and logged.

I quickly realized that star hopping would take too long to find most of the objects and so went to setting circles, which, on Jim's 16-inch, are accurate enough to place most objects in the field of view. Fortunately, I found M-103 relatively easily and by the time I tried for M-74, the sky had darkened enough for me to see it for a few minutes before it set.

Before I knew it, I was caught up in "Marathon fever." By midnight we were both way ahead of schedule, averaging a new object every two minutes. Jim got swept along in my enthusiasm and decided to do the Marathon all over again.

We bogged down in the Virgo cluster area, having to tread our way slowly and make constant reference to Mallas and Kreimer's book, *The Messier Album*. Around 2 a.m. we had seen all the available objects and had an hour's wait to view those that would rise high enough for us to finish off the list.

We grabbed an hour's sleep, which was almost fatal. It was very hard to wake up with enthusiasm and regain our momentum. Nevertheless, by 5:15 we had both logged 109 objects. Neither of us tried for M-30. Jim had made a supreme effort the morning before, even considering chopping down a tree that was partially blocking the horizon. I knew my vision was not as good as Jim's and that if he couldn't see an object, I couldn't.

All in all, however, it was a most successful night. Jim McGaha may be the first person with enough fortitude to do back-to-back Messier Marathons.

Would we do it again? Perhaps, but not this year!

Tim B. Hunter
Tucson, AZ

The Call of the Desert

Sir/ I am responding to your request for dependable viewing sites. For several years I have been enjoying the night sky from the area between the El Paso Mountains and Mojave, California and have rarely been turned back by foul weather. Sometimes it gets a bit windy, but there is almost no light pollution or haze.

This area of the Mojave Desert is easily accessible via well-kept dirt roads leading straight from Highway 58 out into the open desert. The area is very flat and any automobile can reach it.

The area's only possible drawback is its proximity to the Mojave airport and its rotating beacon light just a few miles to the south. However, I hesitate to call this a drawback as the light has not been any hinderance to observing meteor showers or deep-sky objects through my 10-inch telescope. Only about 10° of the sky to the north is obscured by the El Paso Mountains, but the horizon to the south is completely flat and unobstructed so that a nearly total view of the sky can be enjoyed.

You suggested that a "dependable site" should be good enough that a person would risk their annual vacation there. Well, this is, in fact, what I have done these past two years and I plan to spend this year's vacation there, too. I can hardly wait until August!

Bill Mercer Jr.
Bakersfield, CA

Exposure Correction

Sir / There is a major error that appeared in my letter on "Urban Astrophotography" (In Focus, June 1986), which concerned photographing in light polluted skies using an Hα filter. The exposure time is stated as 30 minutes. Actually, an exposure of this length would leave the slide transparent. The actual exposure time is 3 minutes.

Leland A. Dolan
Houston, TX

Halley's Greater Commercial Magnitude

Sir / In evaluating my experience in

observing Halley's Comet, I would say that it was satisfying to be able to follow its course night after night, but as a spectacle, it was a real bust. I never found it close to naked-eye visibility in Sun City. In my opinion, Halley's Comet never got brighter than about 4th magnitude, though I have seen reports, or rather wishful thinking, that put it as bright as 2nd magnitude.

I believe that the way Halley's Comet has been used commercially is disgraceful and in some cases is very close to outright fraud. Even in your magazine, the proliferation of T-shirt, poster, and what-have-you ads tend to dilute the serious nature of the publication.

In our own area, the deluding goes on. One travel agency is even advertising a trip for Australia that starts on June 5 which is touted as a "See Halley's Comet Adventure." I can imagine what a surprise awaits those who take the trip expecting to see a spectacle.

Delmar O. Davis
Sun City, AZ

Ogre Reports Wanted

Sir / I am an astronomer conducting a systematic study of optical flashes of light in the sky. (You may recognize my name: I wrote an article on gamma-ray bursters in the February 1985 issue of *Scientific American*.) I have noticed that several recent issues of ASTRONOMY have carried reports of flash observations. I ask that responsible observers send any additional flash reports to me at the address below. Your report should contain the names of observers, the dates and times of their observations, exposure times and other photo data if pictures were obtained, as well as the reason why the observers thought the flash was not an airplane strobe or other manmade phenomena.

Brad Schaefer
NASA Goddard Space Flight Center
Code 661
Greenbelt, MD 20771

Viewing Venus by Day

Sir / As Venus heads toward greatest eastern elongation, I think it's a good time to view the planet when it's directly overhead, in broad daylight. Just like night observing, the best seeing occurs when Venus is as high as possible. The reduced contrast also provides a sharper view, especially with mediocre optics.

Venus can be spotted with the naked eye when it's far from the Sun. The problem is that the daytime sky becomes Texas-sized when you're searching for one tiny point of light. Here's a trick I've found that works almost every time.

Wait for the crescent Moon, then watch it every evening as it moves eastward. Note the day that the Moon is just a little west of Venus in the western sky. This will provide a point of reference. On the following day, find the Moon when it is high overhead (early afternoon) and then look for Venus, remembering that the Moon has moved about 12° east since the previous evening. You will have a reasonably small area of sky to scan, so you should be able to find it.

Once you've seen Venus with your naked eye, you'll be able to find it with a telescope or binoculars and will soon discover the stillest, glare-free view of Venus you've ever seen.

Peter Wilson
Phoenix, AZ

An Inspiring Instructor

Sir / While flipping through the January 1986 issue of ASTRONOMY, I spied some cartoons that looked remarkably familiar (Stellar Frontiers, "Astronomy and Astrology: East vs. West"). When I turned back a few pages, sure enough, I discovered the article was by George Reed. It was gratifying to discover that he writes just as well as he teaches!

It was Reed's introductory astronomy class several years ago at West Chester State College that instilled in me a great love of the heavens. I remember a particular class, which was held one evening out in a field, where Reed pointed out constellation after constellation.

All I can say is, "What a guy!"

Joanne Mercer

Behind the Scenes

In the Afterglow . . .

Comet Halley did a lot for astronomy. Millions of people worldwide set aside a few minutes — a few minutes stolen from the world of mundane affairs — and looked up at the night sky. Some of them saw Halley but were disappointed by what they saw. Yet many more, watching an astronomical event for the first time in their lives — the cometary wisp fading in the colors of dawn — experienced that intangible something that draws people to the stars. Those who felt it will likely remain aware of, if not actively interested in, astronomy for the rest of their lives.

Those of us who stayed behind in the Northern Hemisphere had our best view in late March. The comet was then bright and active and rose enough before dawn that we could spare a few precious minutes between frantically changing eyepieces, re-focusing and guiding 5-minute exposures with medium-focus telephoto lenses to look at it. Whatever else we may feel about it, Halley offered us a chance to grasp that sublime moment, as the many letters we have received testify.

For the most part, those already-into-it amateurs who traveled the world in search of the comet seem to have accepted Halley's unexpected dimming in early April philosophically. Unfortunately, not everybody had such grace. Some of the big-city news media wrote sarcastic stories about Halley, contending the comet didn't deliver as promised. A lot of amateur astronomers have been around long enough to know the universe doesn't promise anybody a show — it darn well does what it pleases. Besides, everyone who went to Peru, New Zealand, or Australia seriously looking for the comet got to see the southern Milky Way — and that's a sight worth traveling for, comet or not.

Comet Halley will soon be gone, but that doesn't mean the story is over, except for travel agencies and T-shirt companies. Scientific results from Halley's 1985/86 apparition will be coming out for years, and ASTRONOMY will keep on top of that story for you.

Other effects will linger, too. Many of those first-timers who discovered astronomy when they saw Halley with 7x50 binoculars will decide, after suitable reflection and thought, that it's time to buy a good star atlas, a good telescope, and follow the stars.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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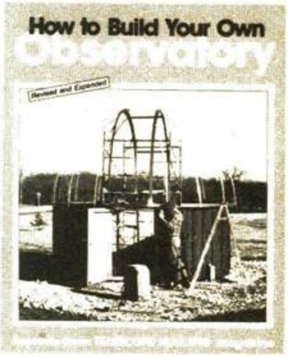

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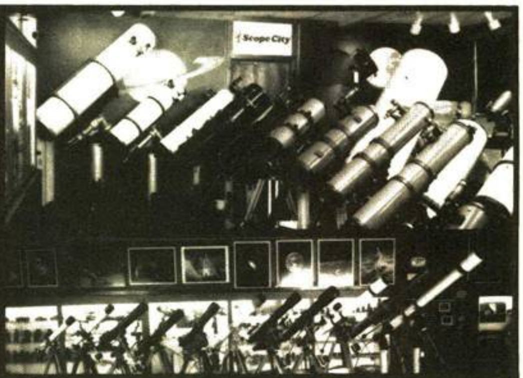

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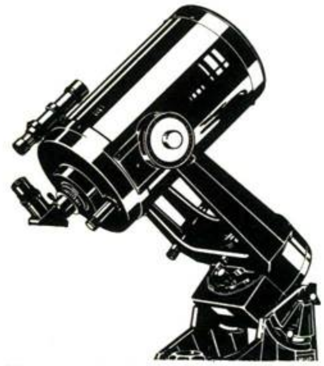

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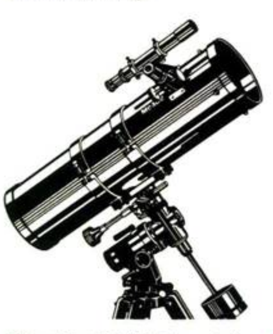

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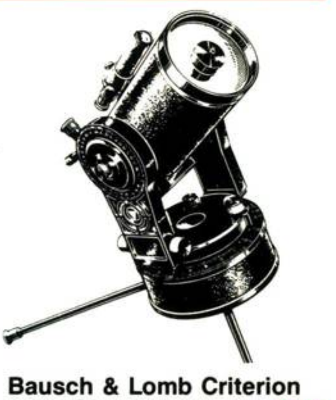

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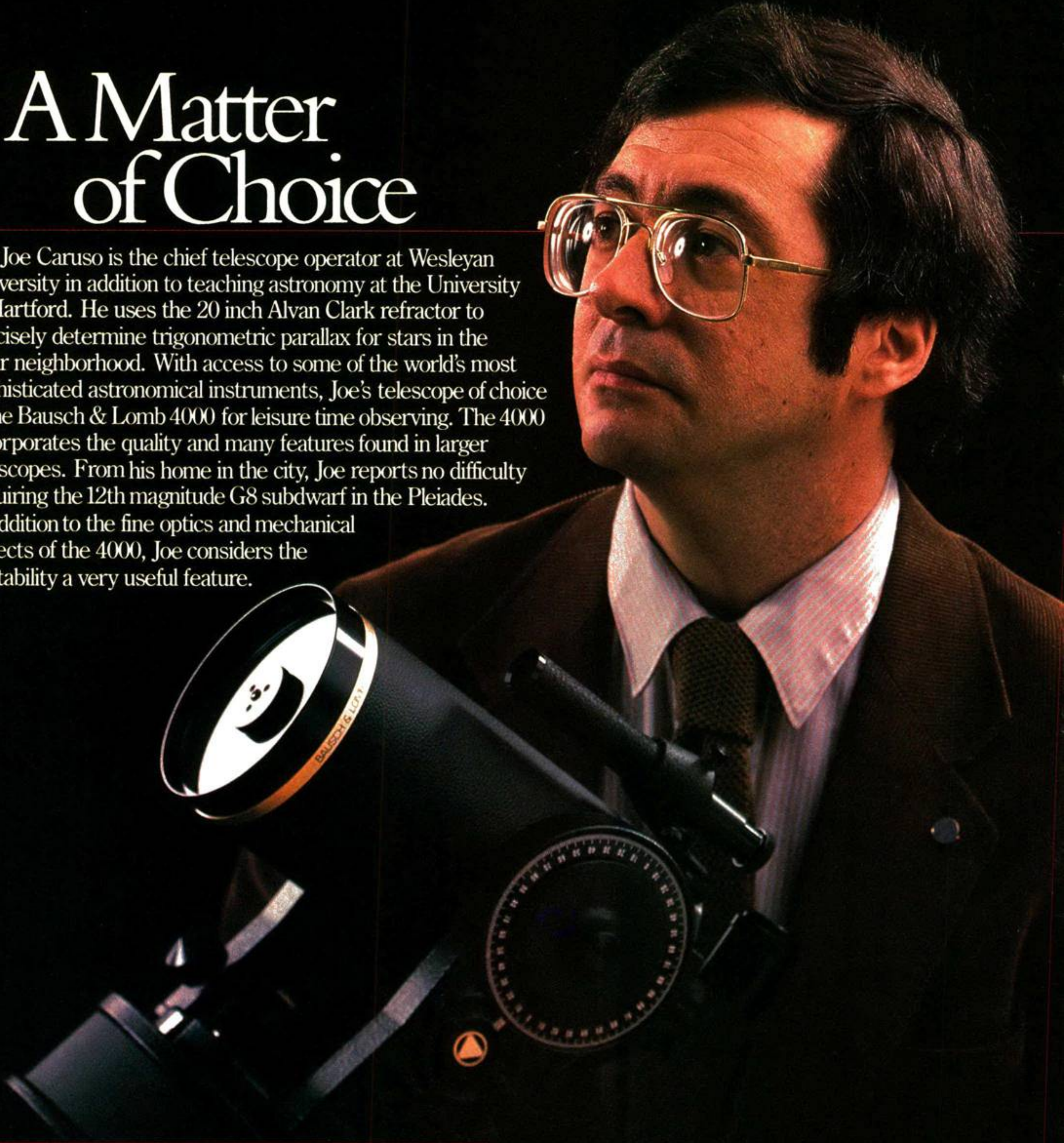
Joe Caruso is the chief telescope operator at Wesleyan University in addition to teaching astronomy at the University of Hartford. He uses the 20 inch Alvan Clark refractor to precisely determine trigonometric parallax for stars in the solar neighborhood. With access to some of the world's most sophisticated astronomical instruments, Joe's telescope of choice is the Bausch & Lomb 4000 for leisure time observing. The 4000 incorporates the quality and many features found in larger telescopes. From his home in the city, Joe reports no difficulty acquiring the 12th magnitude G8 subdwarf in the Pleiades. In addition to the fine optics and mechanical aspects of the 4000, Joe considers the portability a very useful feature.



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ASTRONOMY
Reviews

Infinite Vistas
James Cornell and John Carr, eds.
302 pages, hardcover, $18.95
Scribner's (1985)

Infinite Vistas is the story of the next generation of astronomical observatories and instruments as told by the scientists who are designing them. The large number of contributors results in a distracting unevenness in the style and technical level of the presentation. The book is nonetheless well edited with extensive cross-referencing between chapters, an adequate index, and four pages of recommended reading.

Science writer and astrophysicist Alan P. Lightman introduces the most famous of the forthcoming observatories, the Hubble Space Telescope, which before the loss of the Space Shuttle Challenger was to have been launched in October 1986. In a popular style, Lightman suggests that the Space Telescope will be capable of astrometrically detecting giant planets orbiting about stars as far away as ten to twenty light-years. I doubt, however, that such a project will be deemed sufficiently important to warrant the long observing sessions required.

The HST could improve distance measurements to nearby stars by obtaining their shifting positions against background stars as Earth rotates about the Sun. This would in turn allow improved determinations of the distances to more distant objects through better calibration of standard luminosities. It may even prove possible to indirectly determine whether Cygnus X-1 is in fact a black hole by distinguishing light fluctuations only ten-millionths of a second long. "Such a time interval would indicate an object whose size is ten-millionths of a light-second, about two miles across. Most black holes would be no smaller."

Lightman also discusses the price of all this. The Space Telescope is approximately one hundred times as expensive as recently built ground-based telescopes.

The next generation of telescopes on Earth is discussed by David W. Latham. "It never ceases to amaze me how many groups around the world are interested in building giant telescopes," says Latham. "In the United States alone, at least a half-dozen serious design concepts for telescopes larger than five meters have been described in print," as have others in Europe, Japan, the Soviet Union (25 meters!), and even Saudi Arabia. Latham narrows this list down to the two "giant telescope dreams" that he believes have the best chance of success: the California Institute of Technology and University of California's thirty segment 10-meter telescope, and Arizona's National New Technology Telescope project to combine four giant 8-meter mirrors into a single instrument.

In a highly technical chapter, Robert Stachnik explains how information can be recovered from light distorted by passing through Earth's atmosphere. And Wesley A. Traub describes a 36-meter optical interferometer that could be assembled in space from the Space Shuttle. Such an instrument may be able to resolve globular clusters about other galaxies, see the suspected galaxies surrounding quasars, and observe features on the surfaces of nearby supergiant stars.

Mark J. Reid shows how interferometry can be used at radio wavelengths to produce a telescope as large as Earth itself. But even though radio photons reach Earth's surface, there is an advantage in going into space — to create a longer baseline. A 15-meter radio telescope is to be placed in an orbit that might reach as far as 50,000 kilometers from Earth-based telescopes, producing radio images with ten times the detail possible with even the longest baselines on Earth.

Millimeter and submillimeter wavelengths remain largely unexplored, according to Paul T.P. Ho, despite the fact that most of the sixty-four molecules discovered in the interstellar medium were found at millimeter wavelengths. Radiation at these wavelengths from carbon monoxide molecules was used to map the giant molecular clouds that "as the most massive component of the interstellar medium . . . obviously play an important role in galactic dynamics." Measurements at submillimeter wavelengths could directly determine distances to clusters of galaxies.

Infrared astronomers measure dust. This seemingly mundane substance has enabled astronomers to map the structure of the Galaxy and find what may be the first direct evidence for planetary systems other than our own. Since water vapor absorbs infrared photons, infrared astronomy must be done from high mountains, high-flying airplanes, balloons, or, better yet, from space. Infrared telescopes of all varieties are planned, and even the Space Telescope will be useful at some infrared wavelengths. In fact, Steven P. Willner argues, "Theoretically, at least, it should be much easier to build large telescopes in space than on Earth. . . . When this will happen is anyone's guess, but I will take a chance and predict that by the year 2005 it will be cheaper to build a 15-meter telescope in space than on the ground." However, by then interferometry may make 15-meter telescopes unnecessary!

There is, of course, one star that we have always been able to resolve, even with the naked eye — our own. George L. Withbroe uses Skylab data to show that to understand the Sun we must observe it in wavelengths that never reach the ground. He describes a multi-instrument solar observatory that can first be flown on the Space Shuttle, then mounted on the Space Station.

X-ray and gamma-ray observations have already shown the universe to be an unbelievably violent place. Martin V. Zombeck and Trevor C. Weeks explain that x-ray photons will pass right through mirrors, so x-ray telescopes must have their mirrors placed at very sharp angles. The x-ray photons then graze the mirrors like a stone skips over water and are brought to a focus. Gamma-ray photons are even harder to obtain since nothing will reflect them — they have to be detected directly. Telescopes that concentrate these photons are few and far between. However, when they strike the atmosphere, these photons emit a very brief burst of light, allowing Earth's atmosphere to be used as a telescope of sorts.

One of the most amusing aspects of this book is reading astronomer after astronomer explain why *his* wavelength is the most important to pursue. As George B. Field of the Smithsonian Astrophysical Observatory and Harvard University concludes, these "new tools for astronomy . . . may provide the clues to understanding both the cosmos — and ourselves." *Donald F. Robertson.*

Glimpsing an Invisible Universe
Richard F. Hirsh
186 pages, paperback, $17.95
Cambridge University Press (1985)

Subtitled "The Emergence of X-ray Astronomy," this paperback version of the original hardcover edition provides a historical perspective on x-ray astronomy for the interested lay reader. Written by a history professor, the book covers the period from the late 1950s, when a small core of scientists considered studying high-energy radiation from beyond the Sun, to 1972 when a conceptual framework was developed for solving the question of the mechanism generating this high-energy radiation.

The crucial role played by politics in advancing the discipline — the reaction to the crisis created by the launch of Sputnik, the resulting massive government funding of all related programs in the sixties, and the sharp cutbacks of the seventies — is also discussed.

Molecular Astrophysics
G.H.F. Diercksen, W.F. Huebner, and P. W. Langhoff, eds.
744 pages, hardcover, no price given
D. Reidel (1985)

The NATO Advanced Research Workshop on Molecular Astrophysics was held in Bad Windsheim, West Germany, in the summer of 1984. This volume contains the proceedings of that workshop: a technical discussion on the current state of the art and future directions in molecular astrophysics, covering both observational and theoretical studies.

Evolution of Matter and Energy
M. Taube
289 pages, paperback, $24
Springer-Verlag (1985)

Intended for a wide, nontechnical audience, this book seeks to give a unified description of nature as a basis for analyzing the future of mankind. Taube explores elementary particles, the universe as a whole, the origin and evolution of both matter and life, and the flow of energy and its relationship to the biosphere. From our present knowledge of science, the author concludes that under stable population conditions a long period of human development is possible on this planet. And although colonizing other solar systems in our galaxy is not impossible, it would not offer a solution to continued population growth and is likely to remain technically infeasible.

James E. Keeler, Pioneering American Astrophysicist, and the Early Development of American Astrophysics
Donald E. Osterbrock
411 pages, hardcover, $39.50
Cambridge University Press (1984)

As this biography points out, James Keeler, though his name draws little recognition today, was one of the pioneers of modern astrophysics. Along the path he made in astronomy followed such notables as Samuel P. Langley and Charles A. Young. Keeler was the first to apply physics to the investigation of the nature of stars, nebulae, and galaxies.

The careers of W.W. Campbell and E.E. Barnard, both inextricably related to Keeler's, are also covered as are some of their early major theories and discoveries. In fact, this book is as much about the beginnings of modern astrophysics as it is about one of that science's progenitors.

Photographic Catalog of Selected Planetary Size Comparisons
NASA Technical Memorandum 86207
Stephen Paul Meszaros
140 pages, softcover, $5
NASA (1985)

How big is Olympus Mons, the largest volcano in the solar system? It is one thing to say that it is 650 kilometers wide and over 26 kilometers high, but it is another thing to state that Olympus Mons is as big as Arizona and is over five times as high as Mount Everest. In this new NASA publication, such comparisons are frequently made.

Essentially, the book takes prominent geographical features of the planets and moons (as photographed by planetary probes) and compares them with each other as well as with recognizable regions on Earth, such as states or countries. These features are depicted at the same photographic scale for easy comparison. For example, Texas could fit well into the Orientale Basin on the Moon, and the Valles Marineris, a huge canyon on Mars, could easily stretch from coast to coast across the United States.

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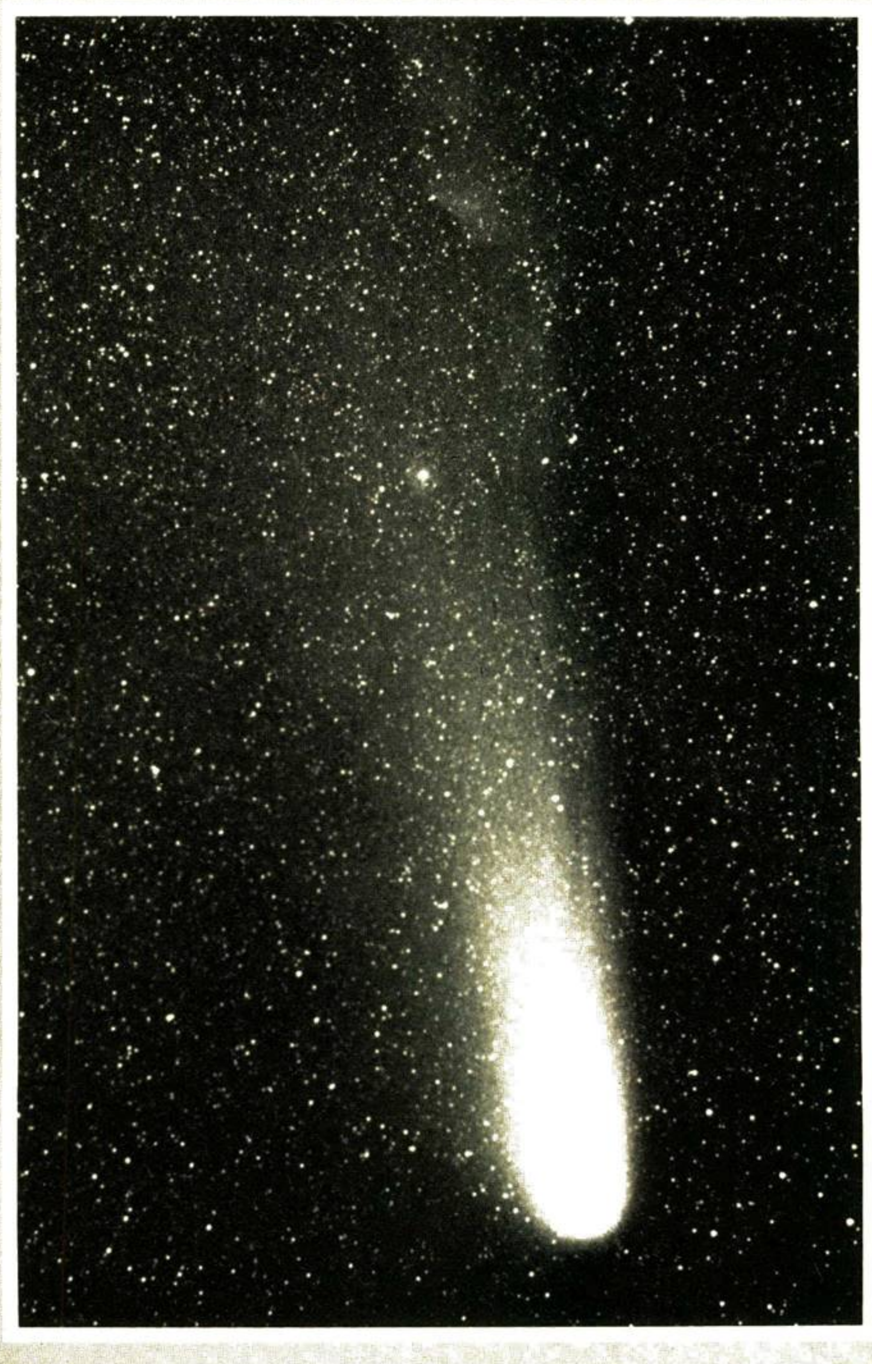
Halley Brightens One Last Time

Proving itself as unpredictable as ever, Halley's Comet followed its disappointing showing in early April by brightening and re-forming a long tail in late April and early May. This baffled observers everywhere — many of whom had traveled to the Southern Hemisphere — since Halley should have become progressively fainter as it drew away from the Sun.

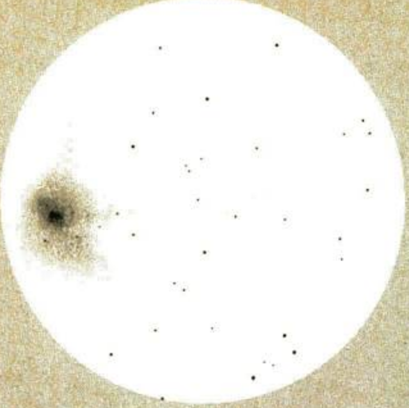
In early April, when the comet reached closest approach to Earth, Halley shone at 6th magnitude and displayed a broad fan-shaped dust tail only a couple of degrees long. Later in the month it gained a magnitude and exhibited a 5°-long gas tail. Early in May, the tail grew to some 8° in length and the comet brightened to 4th magnitude — an incredible feat over a month's time, considering that it was about 60 million miles from both the Sun and Earth.

What happened to the comet during April? Why did it appear impressively bright during the early part of May? The answers are incomplete at best, but there are likely explanations for the comet's freakish behavior. It appears that in early April, several days before closest approach on April 9/10, Halley simply "shut down" — it stopped producing gas and dust. This may have been due to the local surface structure of Halley's nucleus cooling enough at key spots to prevent jets of ionized material and dust from spitting out and forming a larger tail.



Right: On March 21, Comet Halley's tail underwent a major disconnection event visible in this photo as a nebulous kink in the tail. This shot was made using an 8-inch f/1.5 Schmidt camera, hypered Tech Pan film, and a 3-minute exposure. Photo by Adrian New.

Opposite page: On April 14, showing a 90° dust fan and a short bluish gas tail, Halley passed within 1° of NGC-5128. This photo was taken from Cusco, Peru, with a 300mm f/2.8 lens and a 10-minute exposure on 1600 ISO film. Photo by Jack Newton, courtesy Astronomical League Halley Expedition.

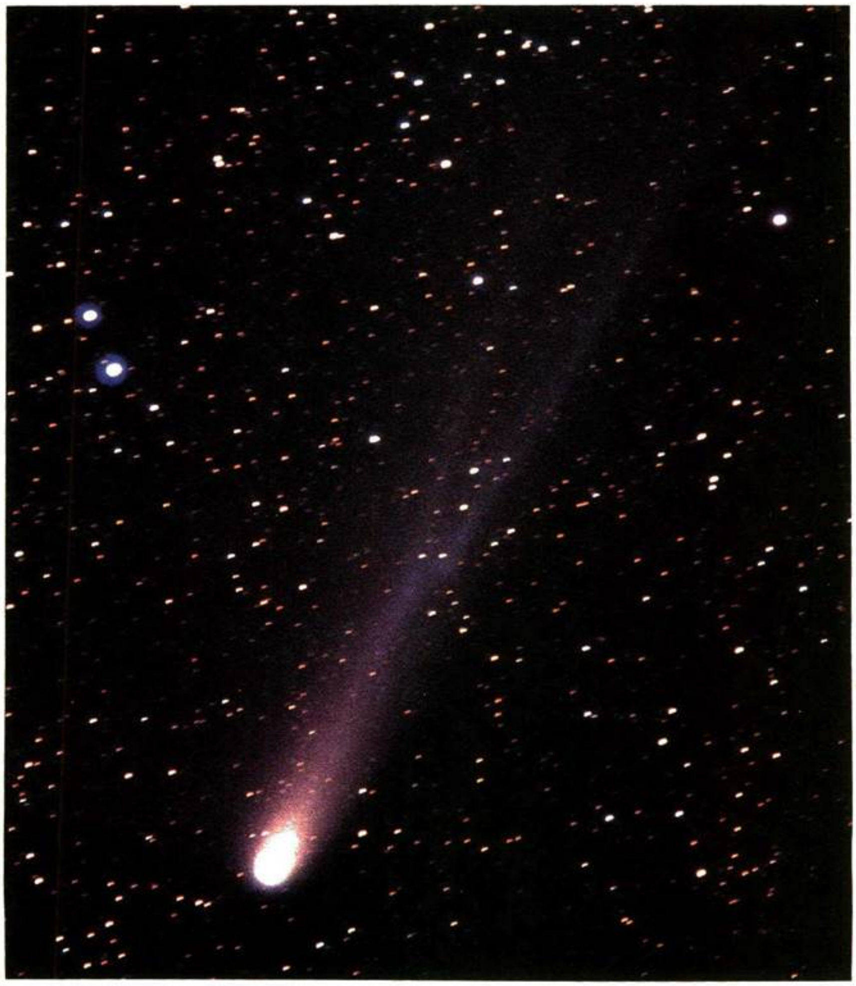


By May 4, Halley had fully regained its lost magnificence — the comet shone at magnitude 5.5, rivaling the nearby star cluster M-35, and its tail spanned some 7°. This sketch shows the comet's appearance as seen in Tucson through a 16-inch f/5 reflector at 65x. The tail appeared broad and bright, the coma seemed adjoined on its sunward side by a bright bow shock of dust, and the inner coma was nearly stellar. Sketch by David J. Eicher.

Above: On April 7, Halley lay in the Milky Way near the stinger of Scorpius. The comet's close proximity to many bright clusters and nebulae, a decreased contrast of the tail against the Milky Way, and Halley's inherent dimness made spotting it tricky. This photo was made in Chile with a 50mm f/1.4 lens piggybacked for 4 minutes and Fujichrome 400D pushed to ISO 1600. Photo by Andrew W. Steinbrecher.

Opposite page: This photo of Halley, made on April 8 from Queensland, Australia, shows the bright coma and nearly stellar inner coma. It is a 30-minute exposure on ISO 1600 film made with a 12.5-inch f/6 scope. Photo by Jim Barclay.

Below: On March 20 Halley showed kinky striations in its ion tail. This is a 350mm f/4.5 lens photo made with Ektachrome 400 and a 30-minute exposure. Photo by Joe Liddell.

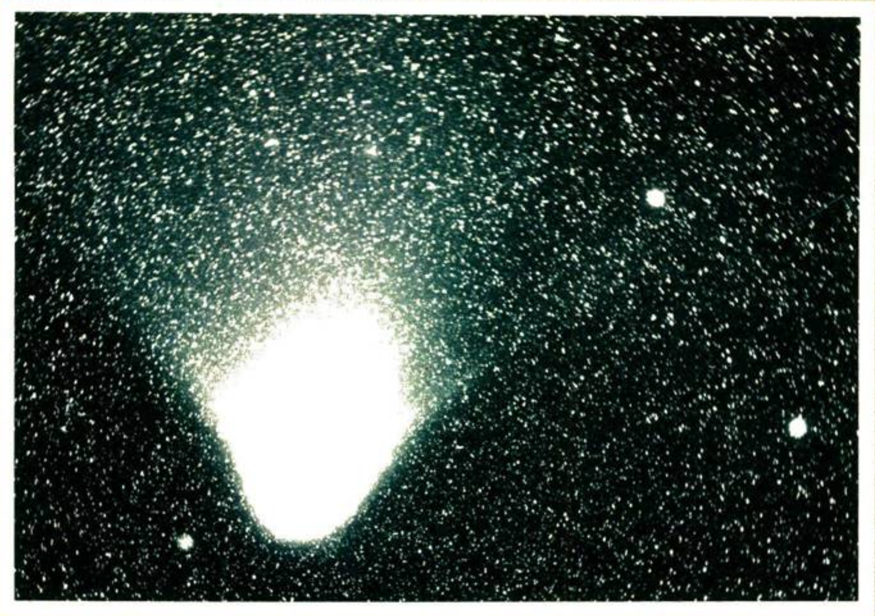


Sometime just after mid-April, however, despite the comet's greater distance from the Sun (tending to make it intrinsically less active) and Earth (decreasing its apparent brightness), Halley's nucleus was heated such that it was "reactivated," producing new jets of gas and dust and re-forming a long tail. This increased activity was noticeable in small telescopes and even binoculars under dark skies.

My first dark-sky view of Halley in May was on the 4th, using the 16-inch f/5 reflector at David H. Levy's observatory near Tucson, Arizona. Along with Stephen M. Larson, David has imaged Halley nearly every clear night for the past six months for the International Halley Watch's Near-Nucleus Studies Net at the University of Arizona's Lunar and Planetary Lab.

By about 10 p.m. we had the 16-inch scope operating. The sky looked very dark and the seeing was steady. To my surprise Halley was rather easily visible to the naked eye in the constellation Hydra. The fuzzy spot of light was elongated, and its coma lay practically on top of the bright star Nu (ν) Hydrae. It appeared much like it had during late March when the tail stretched some 7°, and there appeared to be a wide, bow-shaped curve of dust tail wrapped around the sunward side of the coma.

Through the 16-incher, Halley was far more incredible. At 65x the left side of the field was filled with an amorphous glow (the coma) containing a brighter, smaller condensation of light. In the center of the coma was a curious sight — a tiny, almost starlike point. This indicated that Halley was undergoing an outburst of material, which explains the increased tail activity. Superimposed over the coma was a bow-



On April 14, Comet Halley showed a bright nucleus, a large diffuse coma, multiple dust tails, and a bright, sharply defined gas tail as viewed in a 6-inch f/4 reflector at 70x. Sketch by David H. Levy.

Above: Halley's broad fan-shaped dust tail was observed universally in early April. Robert E. Schmidt of the U.S. Naval Observatory photographed it from Tamarindo, Costa Rica, using an 8-inch f/1.5 Schmidt camera, hypered Tech Pan film, and a 7-minute exposure. U.S.N.O. photo.

Below: By April 28, Halley had once again developed a long ion tail and brightened to about 5th magnitude. This shot was made with a 3-inch f/4 refractor, 098-04 emulsion, and a 20-minute exposure through a yellow filter. During the exposure, a plane and a satellite crossed through the field. Photo by Alfred Lilge.

shaped dust coma formed by the shock wave of the comet colliding with the solar wind. There appeared to be much material on the sunward side of the coma, also indicating lots of outgassing activity. Emanating in the other direction was a bright, sharply-defined ion tail several fields of view long.

On my way to the Texas Star Party in Fort Davis, Lowell Observatory astronomer Brian Skiff and I stopped overnight at Portal, Arizona, a tiny town tucked between mountains near the Mexican border. From that vantage point, Halley appeared to the naked eye comparable in brightness to the star cluster M-35 in Gemini — about magnitude 5.5. Its 7°-long tail was an easy naked-eye object, appearing as a giant Andromeda Galaxy of sorts.

At the Texas Star Party, held between May 6 and 10, hundreds of backyard astronomers viewed Halley and all seemed delighted with the comet's newfound gusto. A 16-inch scope owned by Texan Chris Allen and fitted with a Varo image intensifier showed Halley's stellar nucleus against a sparkling electronic green background. At high power, Oklahoman David Higgins' 17.5-inch reflector revealed a field full of nebulosity surrounding the bright coma. Ed Boutwell's 16-incher in his "Edmond Halley Observatory" showed the dusty bow shock coma as a bright, unmistakable feature.

On the final two days of the Star Party, Halley seemed to brighten still more, up to about 4th magnitude. It was noticeably easier to see as the week progressed.

Comet Halley's rebound in May after a dismal showing in April was startling but not completely unexpected, given the capricious nature of comets. In August it is expected to become lost in the Sun after the last dark of the Moon before its second solar conjunction on September 17.

— David J. Eicher

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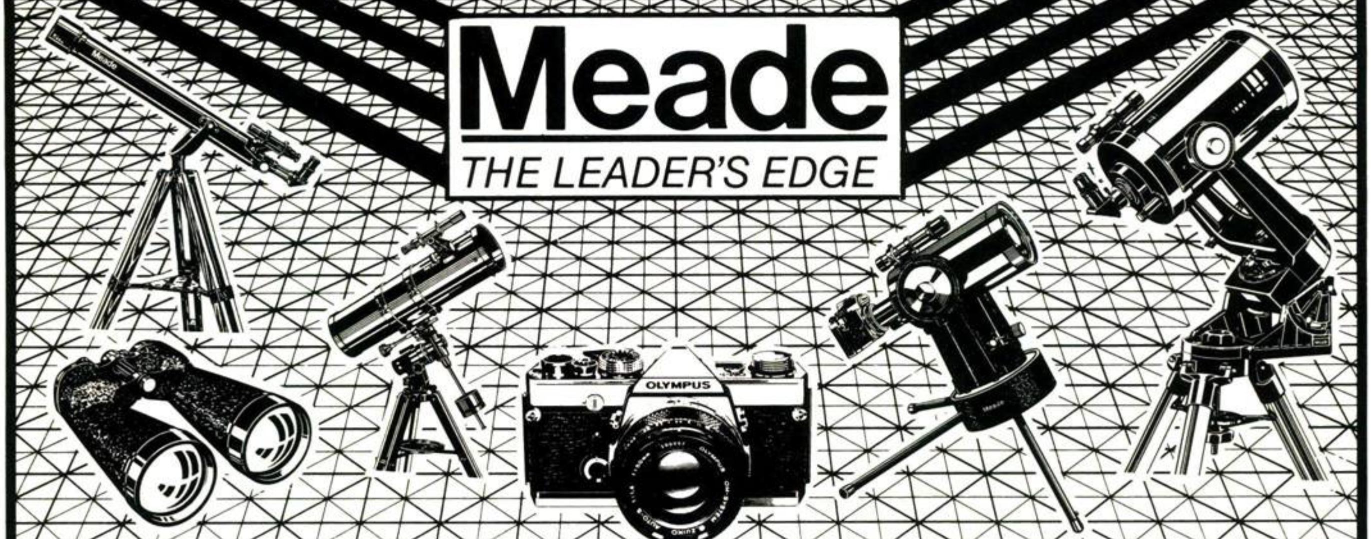

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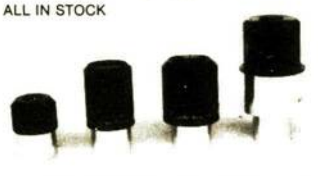

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19mm Wide-Field, 1¼" eyepiece, 85°	**$125**
24mm Wide-Field, "superb", 65°	**$140**
32mm Wide-Field, 2" eyepiece, 65°	**$210**
40mm Wide-Field, "awesome", 65°	**$265**
4.8mm Nagler, 82° field	**$140**
7mm Nagler, 1¼" eyepiece, 82° field	**$175**
9mm Nagler, 82° field, "the best"	**$210**
11mm Nagler, 82° field, 1¼" or 2"	**$225**
13mm Nagler, 82° field, 1¼" or 2"	**$235**

LUMICON®

2111 Research Dr. #5A, Livermore, CA 94550
For phone orders please call (415) 447-9570
LUMICON Products catalogue $2.
Foreign orders add 6% ($8 minimum)
California Residents add 6% tax.
Prices subject to change w/o notice
Hrs: M-F 9am - 5pm; Sat 11am - 3pm

NEW! ENHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 3.1" enhanced silver diagonal mirrors & 2" star diagonal.
The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coa'ed mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32" . **$29.95** 1.52" . **$34.50** 1.83" . **$39.50**
2.14" . **$47.50** 2.60" . **$59.50** 3.10" . **$79.50**
4.25 . **$129.50**

ENHANCED SILVER STAR DIAGONAL

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

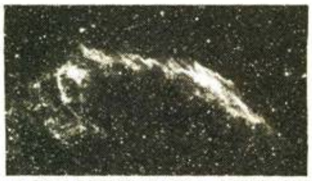
1¼" (1.32" mirror)	**$79.50**
2" (1.83" mirror)(see photo above)	**$129.50**

LUMICON FILTERS STOP LIGHT POLLUTION

UHC Filter™

ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm.


"I CAN SEE THE VEIL NEBULA!"
Rich Zepernick saw the Veil Nebula for the very first time with a LUMICON UHC Filter. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Zepernick, Cresskill, NJ

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter**

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 80-95%.

	Standard	**Premium***
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces		**$79.50**
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS		**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$99.50**	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)		**$299.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	**$79.50**	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$159.50**	**$199.50**
Set of Both 1¼" **DEEP-SKY** and **UHC Filters** (Save 11%)		**$159.50**
1¼" H-BETA Line Filter 9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae)		**$89.50**
48mm "Horsehead Nebula" H-BETA Line Filter		**$189.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines	**1¼" $99.50,**	**48mm $199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm		**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece		**$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece		**$20.00**

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

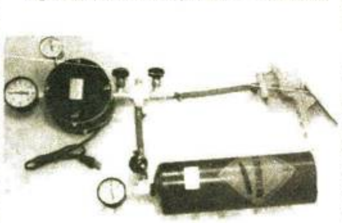
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of nonflammable forming gas & hand-operated vacuum pump.

†Patent Pending

MODEL 100 HYPER-KIT for 35mm film, rolled-up. *Takes longer,* but it easy to use. Not recommended for 2415 . . . . **$225.00**

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295.00**



MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350.00**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller . . **$595.00**

Temperature controller for any HYPER-KIT **$59.50**

Electric Vacuum Pump **$280.00**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X eaiser guide-star selection, use 48mm filters, 360° camera rotation, large prisms fo bright guide-starts. *Specify Camera and Telescope type.*
U.S. Patent # 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$79.50**
Illuminated reticle eyepiece system	**$79.50**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$225.00**

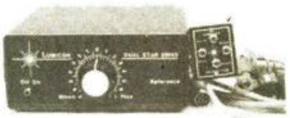
GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER	**$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)	**add $99.95**
Hasselblad adapter	**$195.00**

WHAT DO YOU NEED?

1. **Illuminated reticle eyepiece . . . $79.50** Lumicon 12mm eyepiece system has adjustible L.E.D. illumiation, dual crosslines, battery pack.
2. Cable release for long exposures **$9.95**



3. **LUMICON Quartz Drive Corrector $219** Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.

Declination motor (state telescope) . . $60
NEW Deluxe Digital Qtz. Drive Correc. **$298**

Kodak
SR1600
Scotch
1000

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$9.95**
SR1600, fastest of all, color negs	24	**$12.95**
VR200, fine grain color negs	12	**$9.95**
3M 1000, fastest slide film	20	**$12.95**
Ektachrome 200, fine grain slide	24	**$12.95**
5072, color slides from negs	36	**$6.95**
D-19 B&W Developer	1 gal.	**$6.95**

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Meade® TELESCOPES AT LUMICON

MEADE 2080/LX3 .... $1695

2080/LX3 System w/wedge & tripod ($3000 list)	**$1695**
2080/LX2 System w/wedge & tripod ($2450 list)	**$1495**
NEW! 2080/GEM 8" f/10 w/equatorial mt. ($2100 list)	**$1150**
Multi-coated silvered optics, boost trans. 18%	**add $149**
#36 dual-axis drive corrector control box ($150 list)	**add $99**
#38 declination motor & clutch ($150 list)	**add $99**
Dew shield and accessory tray ($140 list)	**add $89**

2080/LX3

$1695 IN STOCK!

STILL AVAILABLE AT 1985 PRICES!

NEW! Quartz Drive Meade 2080/LX3

The Meade 2080/LX3 with built-in quartz electronic drive system is positively the highest performance 8" Schmidt-Cassegrain telescope system available today.

FEATURES OF THE MEADE 2080/LX3

- ★ Certified diffraction-limited system
- ★ Built-in quartz microelectronic sidereal drive system
- ★ 8x50mm right-angle illuminated Polar viewfinder
- ★ Multi-coated prism star diagonal (99% transmission)
- ★ 25 ft. cord for field operation from a 12V car battery
- ★ 25 ft. cord w/converter for 110VAC 50/60Hz operation
- ★ Output jacks for illum. reticle eyepiece and map light
- ★ Equatorial wedge with compass, bubble level, micro metric azimuth control
- ★ Piggyback camera mount for effortless wide-field photography **(Best to photograph Comet Halley!)**
- ★ Audio cassette explains features, set-up, visual & photographic applications
- ★ Lifetime warranty on telescope, wedge, tripod
- ★ 8" f/10 Schmidt-Cassegrain optics, F = 2000mm
- ★ 20mm Research-Grade Erfle 1¼" eyepiece (100X)
- ★ 7mm Research-Grade Orthoscopic eyepiece (286X)
- ★ High transmission coatings on the front corrector lens
- ★ Ultraprecision 6" LX worm gear motor drive
- ★ Oversize 8.25" primary mirror benefits photography
- ★ Convenient fork mount with slow motion controls
- ★ Best overall mechanical stability of any 8" Cassegrain
- ★ Large right ascension & declination setting circles
- ★ Padded carrying case
- ★ Eyepiece rack
- ★ Latitude scale and no-tool knob set
- ★ Adjustable height heavy duty tripod with eyepiece rack
- ★ Dew shield & accessory tray, optional **add $88**
- ★ Star map & finder cards for Messier objects
- ★ Red astronomer's night flashlight
- ★ **Optional:** Multi-coated/silvered optics boost transmission 18%, **add $149**

2120/LX3 10'' System $2495

The 10" Meade 2120/LX3 collects 56% more light than an 8" telescope for significantly improved viewing and astrophotography. It has all the features of the 2080/LX3 (see above.)

Meade 2120/LX3 w/wedge & tripod ($5000 list)	**$2495**
Multi-coated silvered optics boosts transmission 18%. Highly recommended! ($290 list)	**$195**
#710 dew shield (10") Essential! ($140 list)	**$98**
#36 dual-axis drive corrector control box ($150 list)	**$99**
#38 declination motor and clutch ($150 list)	**$99**
LUMICON Giant EASY-GUIDER/Rich-Field viewer for f/4-f/10 operation (state camera)	**$395**

NEW! 2080/GEM and 2120/GEM

Schmidt-Cassegrain Optics on German Equatorial Mount

2080/GEM, 8" f/10 w/equatorial mount ($2100 list)	**$1150**
Multi-coated silvered optics, boost transmission 18%	**add $149**
2120/GEM, 10" f/10 w/equatorial mount **and with multi-coated silvered optics** ($4300 list)	**$2295**
Dew shield & accessory tray, 8" **$72** 10"	**$144**
#785 motor and quartz drive correc. system ($270 list)	**$198**
#3000 computer control system ($1500 list)	**add $895**

The Meade 2080/GEM and 2120/GEM telescopes include the same diffraction limited optics as the 2080/2120/LX3. Large, stable German equatorial mount with setting circles, slow motion controls on both axes, large 8X50mm finderscope, 25mm 1¼" eyepiece, integrated polar alignment scope, and heavy duty adjustable height tripod (hardwood for 2080, metal for 2120). The computer control provides automatic object location from an extensive software library of deep-sky objects.

4'' MEADE 2045 w/table tripod $695

NEW! Meade 2045/LX3 w/quartz drive	**$885**

IN STOCK!

NEW! 2045/LX3

Meade Model 2045 — Advanced engineering and superb optical performance in a beautiful ultraportable system.

FEATURES OF THE MEADE 2045

- ★ 4" f/10 Schmidt-Cassegrain optics, F=1000mm
- ★ Motor drive for automatic tracking, 110 VAC input
- ★ **LX3:** quartz-controlled elec. drive, 12VDC or 110VAC input
- ★ High transmission coatings on front corrector lens
- ★ Table tripod for easy polar alignment
- ★ 5X24 finderscope & 1¼" right-angle star diagonal
- ★ 1¼" 25mm (40X) and 9mm (111X) eyepieces
- ★ Fork mount with setting circles, manual slow motion

HIGHLY RECOMMENDED OPTIONS

Model 43 drive corrector uses 12VDC ($120 list)	**$96**
See Meade 2080/LX3 options	
Wedge & field tripod as for 2080/LX3 ($470 list)	**$298**
Dew shield ($70) ..... **$49** Solar Filter ($180)	**$139**

OPTIONS BOOST PERFORMANCE

LUMICON UHC Filter for nebulae. Standard 1¼"	**$79**
Prem 1¼", **$99;** Std 48mm, **$159.50;** Prem 48mm,	**$199.50**
LUMICON Deep-Sky Filter, 1¼" Premium	**$79**
48mm Prem Deep-Sky **$119.50, $99.95**	w/Easy-Guider
Adapter for viewing w/1¼" eyepiece	**$20**
Dust covers. Keep optics clean. For 6"	**$16/pair**
8" .... **$20/pair;** 10" .... **$18;** 16"	**$24**
LUMICON Rich-Field Viewer (2080)	**$140**
LUMICON Newtonian Easy-Guider, 1¼" or 2"	**$169**
#122 2X Barlow ($60 list)	**$48**
Dual-axis drive corr. and elec. dec. for 2080/LX2	**$298**
for model 628, 826, DS-10 .... **$340** for DS-16	**$440**
Tele Vue 32mm Plossl 1¼" eyepiece	**$88**
LUMICON Cassegrain EASY-GUIDER for 2080/LX2 & LX/3 (state camera)	**$225**
Illuminated reticle eyepiece & battery pack	**$79.50**

All foreign orders add 6% ($8 minimum)
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Prices subject to change w/o notice
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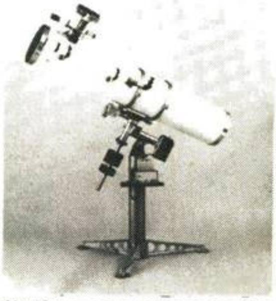
Livermore, CA 94550
Call **(415) 447-9570** for information & orders
Store Hours: M-F 9am - 5pm; Sat 11am - 3pm
All telescopes shipped F.O.B. Livermore

8'' f/6 NEWTONIAN.........$995

BEST VALUE!



STILL AVAILABLE AT 1985 PRICES!

Model 826, 8'' f/6 Telescope w/accessories

Model 628, 6" f/8 with motor drive ($1220 list)	**$785**
Model 628C, 628 w/2" focuser, 8x50mm finder ($1450	**$865**
Model 826C, 8" f/6 with motor drive, #680 2" focuser and 8x50mm finderscope ($1590 list)	**$995**

—Collects 78% more light than a 6" telescope.

These Meade Deluxe Series reflecting Telescopes have superb image quality at low or high power. They include an equatorial mount with motor drive, pier, legs, setting circles, 2" rack & pinion focuser, 8X50 finderscope (628C & 826C only), 25mm (48X) and 9mm (135X) 1¼" eyepieces, altitude and azimuth fine adjustments for polar alignment.

#43 drive corrector uses 12VDC ($120 list)	**$96**
#47M Dual-axis drive corrector & elec. dec.	**$340**
1¼" or 2" EASY-GUIDER (state camera)	**$169**

6'' f/5 NEWTONIAN........$695

IN STOCK!

STILL AVAILABLE AT 1985 PRICES!

Models 6600 (6" f/5) & **8800** (8" f/4.5) telescopes

Model 6600, 6" f/5 Newtonian telescopes ($1300 list)	**$695**
—Best performance & value; bright, wide views.	
Model 8800, 8" f/4.5 Newtonian Telescopes ($1700)	**$895**
—Collects 78% more light than a 6" telescope.	

These meade Professional Series reflecting telescopes yield superb rich-field viewing w/bright images. They include an equatorial mount w/adjustable tripod, setting circles, slow motion controls, 6x30mm view-finder, 1¼" focuser, 25mm & 9mm 1¼" eyepieces & accessory tray.

#784 Quartz motor & quartz drive corrector ($270 list)	**$198**
Basic camera adapter (for moon & planets)	**$32**
1¼" LUMICON Easy-Guider (state camera)	**$169**

16'' f/4.5 NEWTONIAN......$1995

STILL AVAILABLE AT 1985 PRICES!

Meade DS-16A with Accessories

The DS Series of 10" and 16" reflecting telescopes are ideal for deep-sky viewing and photography.

DS-10A, 10" f/4.5 with motor drive ($1600 list)	**$995**
—Gathers 56% more light than an 8" telescope	
DS-16A, 16" f/4.5 with motor drive ($3140 list)	**$1995**
Sealmaster ball bearings, highly recommended	**add $229**
—Gathers 400% more light than an 8" telescope	

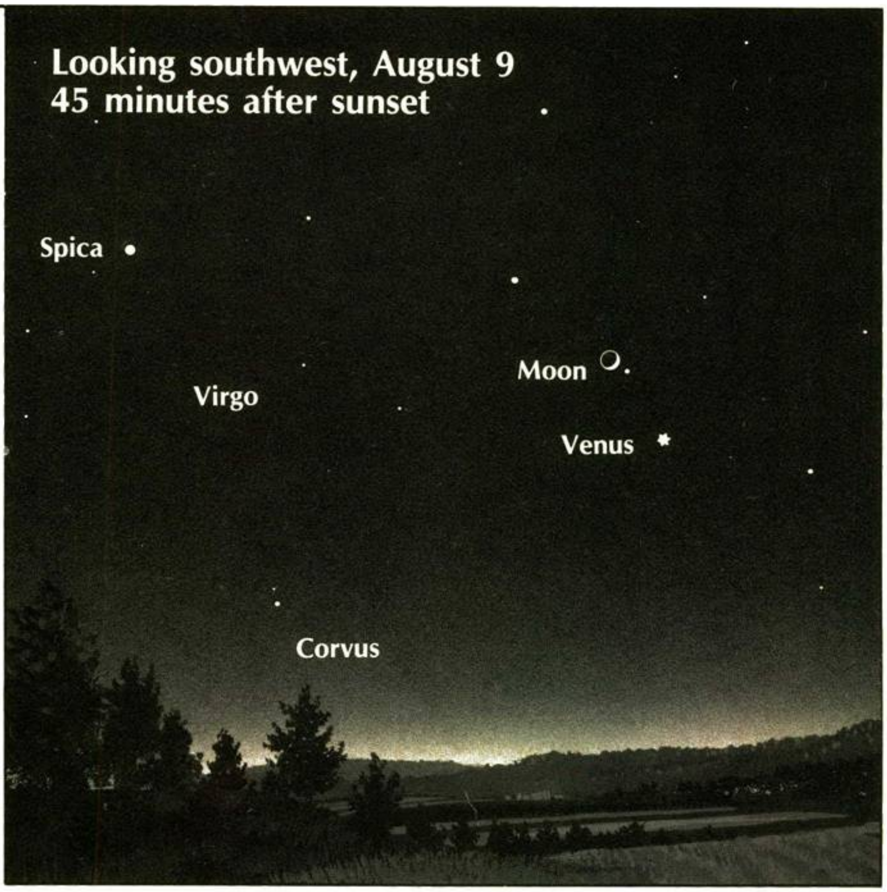
Both the DS-10A and DS-16A telescopes include an equatorial mount, #680 2" focuser, motor drive, setting circles and 25mm 1¼" eyepieces. The DS-10A is shipped freight collect.

6x30mm finderscope with brackets ($56 list)	**$42**
8x50mm finderscope with brackets ($130 list)	**$96**

Eye on the Sky

Perseid Meteors at Their Best

by Robert Burnham



The Wanderers

Skywatching in August can be a grim business: if the warm humid skies aren't too hazy for viewing, whining clouds of insects are swarming around you! Unfortunately, the buggy evening hours this month offer your last good opportunity to observe the planet **Venus** before it slips too low in the sky. With a brightness of magnitude −4.2, Venus is easy to identify even through the trees, but its low elevation (roughly 10°, 45 minutes after sunset) may require that you seek a location with an unobstructed view to the west.

Venus reaches its greatest angular separation from the Sun on August 27 (46°), but it remains low because the ecliptic, the imaginary line in the sky that the planets lie along, meets the sunset horizon at a very shallow angle this time of year. As a result, Venus sets only two hours after the Sun, just as twilight is fading into night. Venus is among the stars of Virgo and lies less than a degree away from 1st-magnitude Spica in the evening sky on August 30.

As Venus sets, **Saturn** is distinctive in the southwestern sky among the stars that form the Claws of Scorpius. Creamy-white in color and at magnitude 0.4, Saturn lies near the northern Claw, the 3rd-magnitude double star Beta (β) Scorpii, a pretty sight in binoculars. Although Saturn isn't in conjunction with the Sun until December, its low southern declination will make it hard to see after September.

At the end of twilight this month, the Red Planet **Mars** is almost due south. Now that it is past opposition, it will grow steadily dimmer as the distance between Earth and Mars lengthens. On the 15th, Mars shines at magnitude -2.2, adding a brilliant amber-hued "star" to the Teapot asterism of Sagittarius. Mars spends all of August in the Teapot's handle, yet by month's end it is moving eastward toward Capricornus. On the 16th, the Moon occults Mars, but the event is visible only from northeastern and central Africa and southern Asia.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Jupiter is the brilliant white "star" rising in the southeast during late twilight. The King of Planets shines at magnitude −2.8, rendering the dim stars of Aquarius all but invisible by contrast. It is moving retrograde (westward), but you will have a hard time gauging its motion with no bright stars nearby.

About two hours after Jupiter crosses the meridian, the elusive planet **Mercury** rises in the east. On August 11, Mercury reaches its greatest angular separation from the Sun (19°), and on that morning will be about 7° high 45 minutes before sunrise. In fact, from August 5 to 21 Mercury's elevation in the predawn sky ranges from 5° to a maximum of 8° on the 14th. Mercury appears creamy-orange in color and will have a brightness of magnitude −0.3 on the 14th. If you have trouble spotting it, use binoculars to scan the eastern horizon as morning twilight comes on.

This year's **Perseid meteor shower** promises to be a good one. Peak activity occurs at 7 a.m. EDT on the 12th, comfortably close to the hours after midnight on the night of the 11th/12th. In addition, the First Quarter Moon will have set by about 11:30 p.m. — so from a dark suburban location, look for about 30 meteors an hour coming from the region of the Double Cluster between Perseus and Cassiopeia.

Bathed in the reddish umbral shadow of the Earth, the Moon reaches total eclipse just before setting over the San Francisco Bay area on April 24, 1986. This photo by Jacques Guertin was made using a 300mm 8-inch Schmidt camera and Fuji 50D transparency film piggybacked on a 16-inch telescope.

The Starry Sky

If you can get away from city lights and star watch under a truly dark sky only once a year, do it this month or next. From the 1st to the 10th and from the 27th to the 31st this month are the nights of the "dark of the Moon" when the sky reveals its stellar glories at their best.

At a dark-sky site, the most prominent celestial feature is the **Milky Way**. Starting broad and bright in the south and flanked by two planets (Saturn in Scorpius and Mars in Sagittarius), the Milky Way drifts upward like silvery smoke. It splits in two between Scutum and Cygnus and then rejoins overhead to continue, dimmer now, down through Cassiopeia to meet the northeastern horizon in Perseus. If you have binoculars, scan its entire visible

August Night Sky

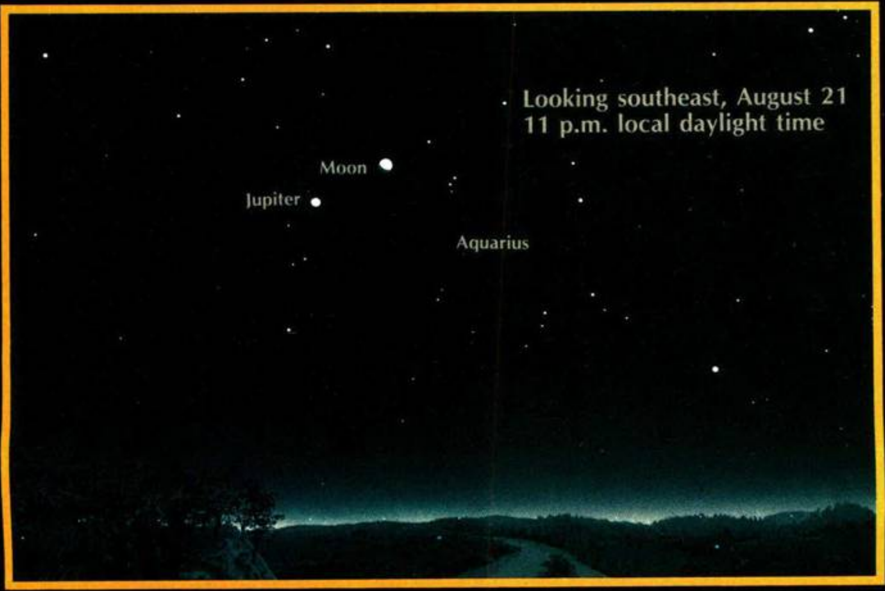
New Moon
August 5
2:36 p.m. EDT

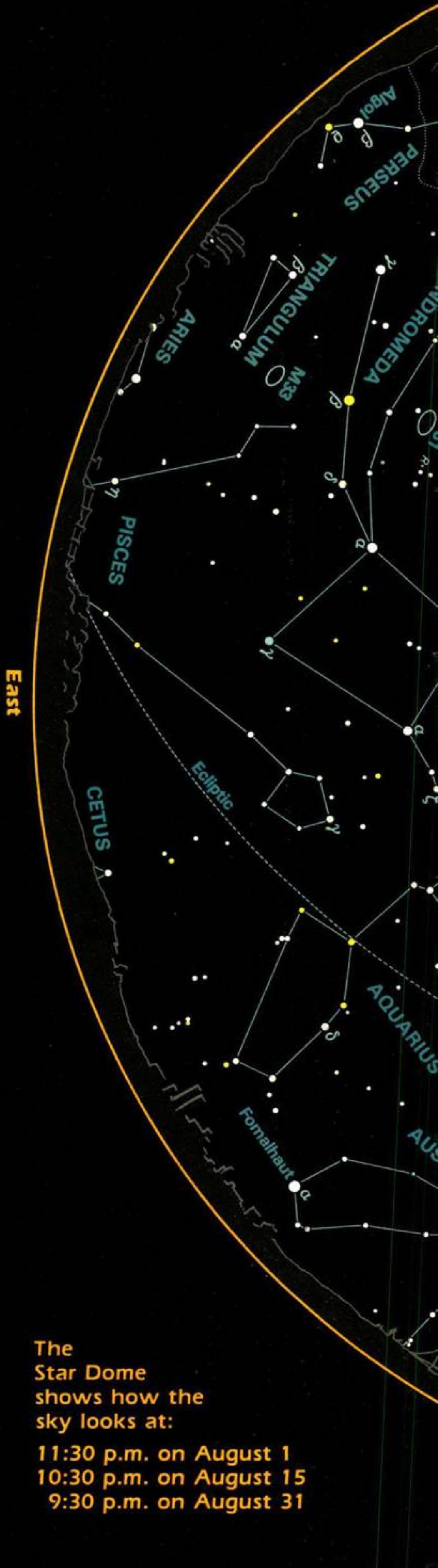
First Quarter
August 12
10:21 p.m. EDT

Full Moon
August 19
2:54 p.m. EDT

Last Quarter
August 27
4:38 a.m. EDT

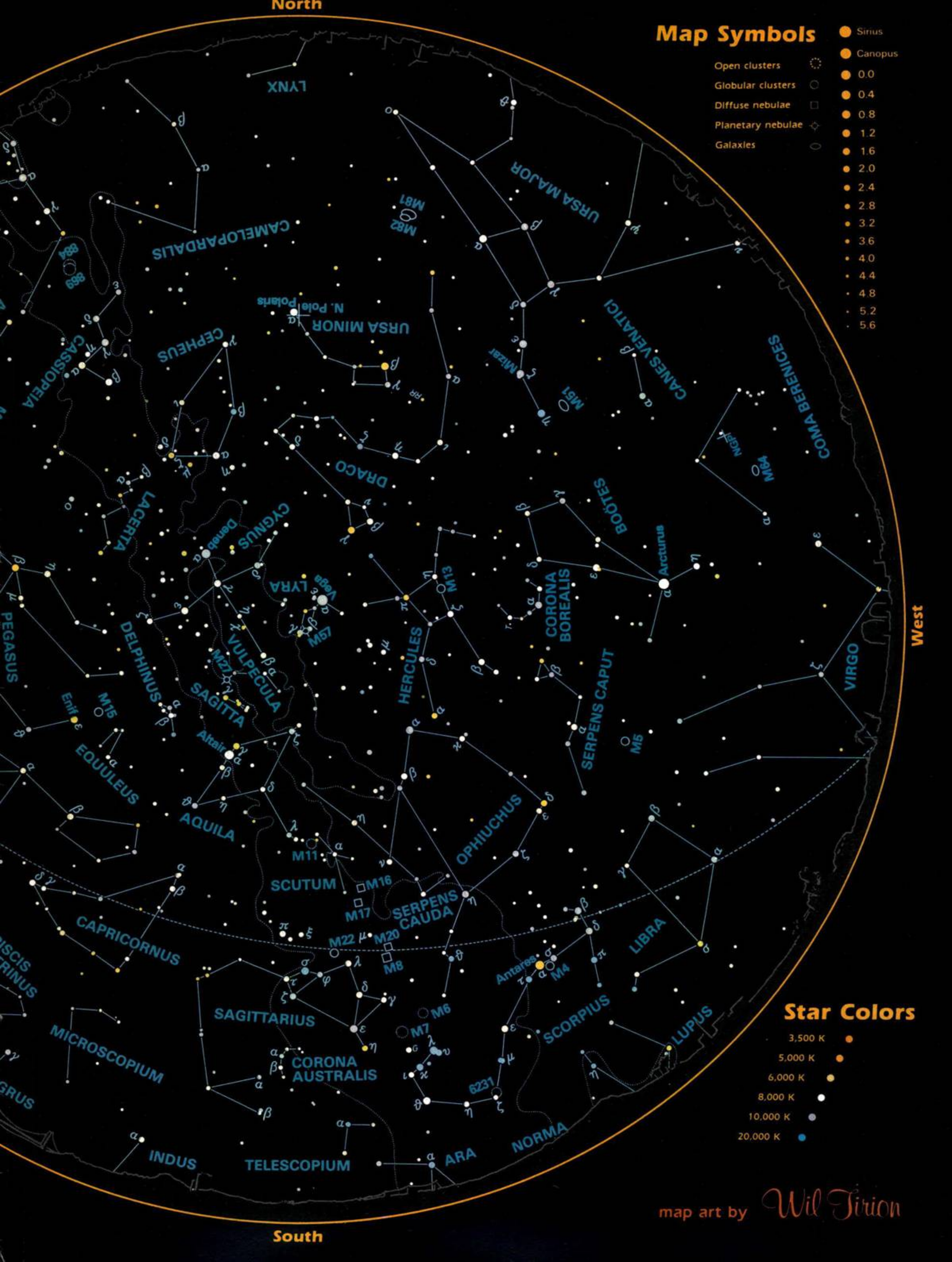
5th	New Moon occurs at 2:36 p.m. EDT. From today until the 21st, Mercury will be at least 5° high in the northeast, 45 minutes before sunrise.
9th	The Moon will lie to the left of Venus in the evening sky tonight.
11th	Mercury is at greatest western elongation in the predawn sky.
12th	First Quarter Moon is at 10:21 p.m. EDT. Perseid meteors reach peak activity in the predawn hours. Look for about 30 bright meteors an hour coming from the region near the Double Cluster between Perseus and Cassiopeia.
14th	Mercury reaches a peak elevation of 8° in the morning sky, 45 minutes before sunrise. An occultation of Antares by the Moon is visible over eastern Europe, Asia, and the Philippines.
16th	The Moon is closest to Earth at 12:39 p.m. EDT: 365,710 kilometers. An occultation of Mars by the Moon is visible from parts of Africa and southern Asia.
19th	The Moon is Full at 2:54 p.m. EDT.
21st	The Moon and Jupiter will rise near each other tonight.
27th	Last Quarter Moon occurs at 4:38 a.m. EDT. Venus is at greatest eastern elongation (46° from the Sun) in the evening sky.
28th	The Moon is farthest from Earth at 10:43 a.m. EDT: 404,368 kilometers.


Looking southeast, August 21
11 p.m. local daylight time



The
Star Dome
shows how the
sky looks at:

11:30 p.m. on August 1
10:30 p.m. on August 15
9:30 p.m. on August 31


North
Map Symbols
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
LYNX
URSA MAJOR
M81
M82
CAMELOPARDALIS
884
869
N. Pole
Polaris
URSA MINOR
CEPHEUS
CASSIOPEIA
CANES VENATICI
COMA BERENICES
Mizar
M51
NGC
M64
DRACO
LACERTA
CYGNUS
Deneb
BOÖTES
Arcturus
LYRA
Vega
M57
M13
CORONA BOREALIS
HERCULES
PEGASUS
DELPHINUS
VULPECULA
M27
SAGITTA
Enif
M15
EQUULEUS
Altair
AQUILA
SERPENS CAPUT
M5
West
VIRGO
OPHIUCHUS
M11
SCUTUM
M16
M17
SERPENS CAUDA
CAPRICORNUS
M22
M20
M8
Antares
M4
LIBRA
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LUPUS
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SAGITTARIUS
M6
M7
MICROSCOPIUM
CORONA AUSTRALIS
6231
GRUS
INDUS
TELESCOPIUM
ARA
NORMA
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K
South

map art by Wil Tirion
]

Top: On March 5, 1986, Comet Halley could be seen crossing Capricornus and edging toward the Sagittarius border. Photo by Jerry Schad.

Bottom: Fifteen days later, Halley moved into the starfields of Sagittarius, its tail pointing toward the Teapot asterism. Photo by Steve House.

length slowly.

The center of the Galaxy lies halfway between the emission nebula M-8 in Sagittarius and the star in the tail of Scorpius marked Lambda (λ). It is invisible from Earth, hidden by thousands of light-years of interstellar dust, but even your naked eyes tell you the Milky Way is denser here.

In the southern sky the hook-shaped stinger of **Scorpius** the Scorpion curls as it holds Saturn in its Claws, and ruddy Antares stares balefully at it. In some myths, the scorpion killed Orion and was banished here, half a sky away from its victim. Across the Milky Way lies **Sagittarius** the Archer, with the planet Mars caught in its Milk Dipper asterism (Phi [ϕ], Zeta [ζ], Tau [τ], Sigma [σ], and Lambda [λ] Sagittarii).

Between Sagittarius and Scorpius lies the Tail of the Serpent **Serpens Cauda**, held fast by the Serpent-Bearer, **Ophiuchus**, who also holds the Snake's Head Serpens Caput. North from **Serpens Cauda** is a small constellation originally called Scutum Sobiescianum — Sobieski's Shield — and now simply known as **Scutum**. Along with several other groups, a few of which we'll meet this month, Scutum was invented by Johannes Hevelius (see Skylore) to honor the king of Poland in the mid-1600s, Jan Sobieski III. Above Scutum flaps **Aquila** the Eagle, whose brightest star, a white 1st-magnitude gem, is called Altair.

Squeezed between Aquila and Cygnus lie **Sagitta** the Arrow and **Vulpecula** the Little Fox. The ancient Greeks created Sagitta, which indeed resembles its name. It was supposedly fired from the bow of **Hercules**, who lies to the west of the Milky Way beyond Lyra. Vulpecula was created by Hevelius and was originally called Vulpecula cum Ansere — the Fox with a Goose.

A little to the north, a far more impressive bird than Aquila accompanies the Eagle on its southward flight: **Cygnus** the Swan. For viewers in the middle northern latitudes, Cygnus passes directly overhead and is especially striking. Its brightest star is called Deneb. Marking the Swan's beak is a double star named Albireo that good binoculars will split into two component stars, one of them blue and the other gold.

The celestial Lyre, **Lyra**, lies next to Cygnus. It has a bright blue-white star, Vega, and an intriguing variable star, Beta (*β*). Vega is constant at magnitude 0.0, but once every 12 days and 22 hours, Beta changes brightness from 3.4 magnitude to 4.3 and back again. Joined with Deneb in Cygnus and Altair in Aquila, Vega forms the Summer Triangle, a prominent asterism this time of year.

Turn now to face northeast. High overhead in the region between Deneb and the house-like shape of Cepheus, Hevelius added another constellation, **Lacerta** the Lizard, using a number of 4th-magnitude stars. Although it is dim, Lacerta's scampering zigzag is distinctive when you finally locate it. Near the Lizard is **Cepheus**, a mythical King of Aethiopia, husband to Cassiopeia (located down the Milky Way a little), and father to Andromeda (now rising in the northeast). These constellations, however, belong to autumn and we'll see them better in a month or two.

Skylore

In the mid-1600s, the Baltic city of Danzig (now Gdansk, Poland) was a busy seaport and commercial hub. One of its leading citizens was the town councilor and brewery owner, Johannes Hevelius. Bitten by the astronomy bug, Hevelius spent most clear evenings on top of his house where, spreading across his own rooftop and two adjoining ones, he had the best-equipped observatory in Europe.

Hevelius' astronomical interests covered a wide range. His first published work was a large folio on the Moon, *Selenographia*, which contained the first accurate telescopic map of the lunar surface. Although Hevelius' system of lunar nomenclature didn't survive (he named lunar features after terrestrial geography; Copernicus was Mt. Aetna, for example), a few of his names, such as the lunar Alps and Apennine mountain ranges, have endured.

Yet it was his work as a stellar cataloguer and cartographer that Hevelius felt was most important. Fired with enthusiasm in his youth by the example of Tycho Brahe, the adult Hevelius set about building the best astronomical instruments possible. First copying and then improving on the instrument designs of Tycho, Hevelius began work on a star catalogue larger than his predecessor's and far more accurate.

For positional measurements, Hevelius remained stubbornly loyal to one instrument feature that struck his English contemporary, Robert Hooke, as backward, illogical, and absurd: Tycho's old-fashioned, naked-eye sights rather than the newly invented telescopic ones with cross hairs. Hooke, never tactful in a dispute, heaped public scorn on Hevelius' method and ridiculed his results. Since Hevelius was a distinguished and valued foreign member of the Royal Society of London (to which Hooke also belonged) and since no one could resolve the unseemly dispute by correspondence, the Royal Society sent a skilled and congenial astronomer-emissary off to Danzig to see just how good Hevelius' methods were.

Arriving in May 1679, this representative spent two pleasant months with the great Hevelius, staying up late, trading astronomical gossip, and testing Hevelius' observations against his own with the same equipment. The conclusion, much to the young Englishman's astonishment, was that Hevelius indeed could squeeze great accuracy out of his naked-eye sights and, given the troubles to which the new telescopic sights were prone, Hevelius was probably better off sticking to a system in which he thoroughly understood the potential errors.

Soon after the young astronomer returned to England — where he would make the first-ever prediction that a certain comet would return seventy-six years after its last appearance — catastrophe struck Hevelius. One windy night in late September 1679, a grudgeful servant deliberately left a candle burning in the stables attached to the house. No one was hurt in the resulting blaze but by the time the fire was quenched, nearly all of Hevelius' manuscripts were destroyed, together with his house and the great observatory.

Although he was sixty-eight years old and faced with a disaster few would have recovered from, Hevelius promptly started over.

Less than two years later, he had rebuilt his observatory and was back measuring the stars and amassing observations to complete his greatest work, the *Prodromus Astronomiae*, or "Forerunner of Astronomy," a manuscript that had been one of the few saved from the fire. The book was to consist of three parts: a commentary on several astronomical topics, a star catalogue, and an atlas.

Unfortunately, when Hevelius died in 1687, the star catalogue portion of the *Prodromus* was only half-finished, containing positions for roughly 1,600 stars. But rather than let the incomplete work go to waste, his widow saw the book through the press and it appeared in 1690. In the beautifully engraved atlas, Hevelius portrays several new constellations of his own invention: Canes Venatici, Lacerta, Leo Minor, Lynx, Sextans Uraniae, Scutum Sobiescianum, Triangulum Minus, Vulpecula cum Ansere, Cerberus, and Mons Moenalus.

With the death of Hevelius, modern astronomy's infancy came to a close. He was the last of the naked-eye positional observers and the last major observer to make all of his own instruments. Even before his death, however, the trend of the future was clear. The French and English established their respective Royal Observatories in 1671 and 1676, making astronomy a nationally-funded pursuit.

When the International Astronomical Union fixed the constellation boundaries in 1930, it is pleasing to note that while many constellations created over the last 500 years were abandoned, most of those proposed by Hevelius were kept.

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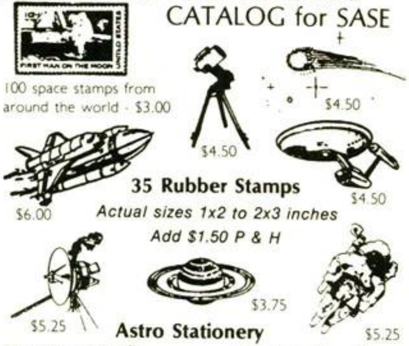
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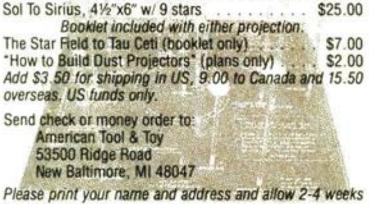

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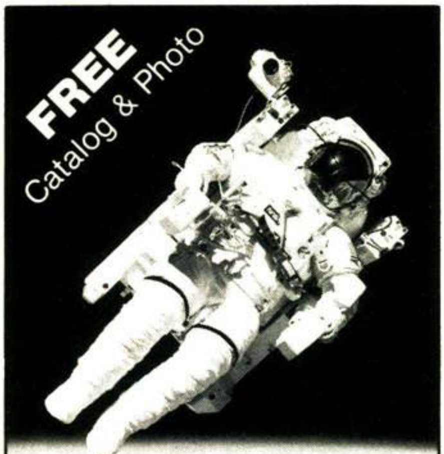

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Camera Lenses For Deep-Sky Astrophotography

by
Matthew F. Willson

Lenses for 35mm SLR cameras come in all shapes and sizes. There are "mirror-lenses," "normal" lenses, telephoto lenses, wide-angle lenses, and exotic fish-eye lenses. Prices range from $49.99 to about as high as you can imagine. If you're considering purchasing a new lens or if you already have an assortment of lenses but can't decide which to use for a particular subject, here are some hints on selecting and using lenses for astrophotography.

The "Normal" Lens

Nearly all 35mm cameras come equipped with a "normal" lens. These have focal lengths near 50 millimeters and commonly open up to f/1.4, f/2, or f/2.8. Though these lenses seem commonplace, don't underrate their ability. A lens with an f/1.4 focal ratio has an aperture of 35mm and is quite capable of putting a good, solid image of a magnitude 6.9 star on film in one minute. (Please don't quibble. I am using this magnitude figure mainly for comparison. It is not the "limiting magnitude," and, of course, any such figure depends on film speed and other factors, too.)

A 50mm lens records a field of view 27° by 40° on 35mm film. The constellation Orion fits with room to spare across the short dimension; Cygnus fits with ease down the long dimension. A 50mm lens is perhaps the most versatile for astrophotography and a good choice for photographing whole constellations with a reasonable amount of detail. If you want to buy the lens by itself, you won't have to spend more than $150 and for that you will get top-notch optics.

Given the utility of the "normal lens," why even bother with other lenses? The answer is that the others can do what the 50mm lens cannot do.

Wide-Angle Lenses

With optics ranging in focal length from super-wide 18mm to an almost normal 40mm, wide-angle lenses let you shoot vast expanses of the sky. Sounds great, doesn't it? The drawback is that what you gain in "big picture" coverage you lose in detail when the resulting photos are compared to those covering less sky. An 18mm wide-angle lens, for example, covers a field 67° by 90°, but the image it forms of the Pleiades will appear only about 0.5mm across. This famous naked-eye star cluster won't even be resolved into individual stars. Clearly such a lens isn't the top choice for detail work. But just think — in one frame you could capture the Milky Way all the way from Scorpius' tail to Albireo in Cygnus!

Another disadvantage of a short focal-length lens is its tiny aperture. When opened to f/2.8, an 18mm lens has an aperture of 6.4mm, which in a 1-minute exposure will record nice images of stars down to magnitude 3.5. In comparison, a 50mm lens at f/2.8 with an aperture of 18mm would capture stars down to magnitude 5.4 in the same amount of time. Because stars are point sources of light, it's the aperture, not the f/ratio, that affects their brightness on film. The larger your objective is, the more stars you can record in a given amount of time. Of course, for extended objects like the Milky Way, wide-angle lenses still obey the relationship between f/ratio and image brightness. (We'll say more about this later.)

Admittedly, an 18mm wide-angle is an extreme wide-angle lens. A more conservative choice would be a 28mm or 35mm lens. These are readily available at reasonable prices and are very handy for terrestrial photography, too. A good-quality wide-angle lens can be had for less than $100, and a high-quality one for under $200. If you buy a used one, it can be even cheaper.

Fish-Eye Lenses

For the photographer who can't get enough sky, there are fish-eyes. These lenses cover fields of 180° or more. Just imagine pointing your camera straight up and photographing the entire sky on a single frame of film. Wow! Their main drawbacks are the same as with wide-angle lenses — you trade off detail for breadth of field.

Fish-eyes range from 6mm to 16mm focal lengths for 35mm cameras, with speeds as fast as f/2.8. The short-focus ones, those with focal lengths around 8mm, produce a circular image on the film. Those with 16mm focal lengths cover 180° corner-to-corner across the 35mm frame.

Unlike conventional wide-angle lenses, fish-eyes distort the field near the edge. This means that straight lines come out curved. This isn't much of a problem if you're photographing the Milky Way from Perseus to Scorpius or a fantastic sky-filling display of Northern Lights, but it does lead to odd-looking results in terrestrial use. Fish-eye lens prices range from $150 to $4,000.

The 135mm Telephoto

Several steps up from the "normal" 50mm lens is the 135mm telephoto. A lens of this focal length produces an image a bit less than three times the image scale of a 50mm lens. Since this lens covers a field 10° by 15°, the southern section of Orion just fits across the 24mm dimension of a 35mm film frame, and the Teapot of Sagittarius just fills the frame.

Lenses of this size typically open up to f/4, f/3.5, or f/2.8, and a few even have f/1.8 as their widest stop. At f/3.5, a 135mm lens has an aperture of 39mm and can record stars to magnitude 7.2 in 1 minute, or only slightly fainter than a standard 50mm f/1.4 lens. Lest you get the impression that the telephoto lens is no better than the 50mm lens, consider the following. Before sky fog overexposes the film, what is the longest exposure possible with an f/3.5 lens versus the longest exposure for an f/1.4 lens? The slower f/3.5 lens lets you expose the film roughly six times as long, ultimately reaching stars one-sixth as bright or two magnitudes fainter.

At the larger image scale of the 135mm lens, star clusters and nebulae are better resolved than they are with shorter lenses. The Pleiades, which appears unacceptably small through an 18mm lens, comes out 4.7mm across on film shot with a 135mm

telephoto. The cluster will be well-resolved and may even show traces of the nebulosity veiling Merope with a long exposure.

The prices of good 135mm telephoto lenses run between $150 and $300, though lenses of reasonable quality are available even below that range.

A Brief Digression

By now you might be wondering how to figure out the field of a lens. It's actually quite simple using this tried and true formula:

$$S = A \times F/57.3$$

where S is the size (in millimeters) of any astronomical object on film, A is its angular size (in degrees), and F is the focal length of the lens (in millimeters). You can use this formula to work out the size of a target on film when using a particular lens.

For example, given a 135mm lens and the angular size of the Pleiades as 2° we get:

$$2 \times 135/57.3 = 4.71\text{mm}$$

The result is the size of the image on the emulsion. The Moon is a handy object for comparison. It is 0.5° across. How big would the image of the Moon be with each lens?

We can turn this formula around to find the angular coverage of a given camera lens. It then becomes:

$$A = 57.3 \times S/F$$

Notice that S is the length or width of the 35mm film frame. Let's use this formula to determine the sky coverage of a homemade 92mm lens. A 35mm film frame is actually 24mm by 36mm. Start with the short dimension:

$$57.3 \times (24/92) = 14.94°$$

That's the coverage on the short dimension. In the 36mm dimension, the field is 22.4°. By changing the frame size, this formula will work in any format. Bear in mind that the formula is an approximation that's inaccurate for wide-angle lenses, though it's good enough for telephotos. For an 18mm focal length, the formula gives a field of 76° by 115°. The actual field is 67° by 90°.

50mm ⌂ **Even the humble "normal" lens can perform wonders when applied to sky photography. This 20-minute exposure, shot on Ektachrome 400 film at f/2.8, shows a wealth of Milky Way detail and thousands of faint stars. Photo by Dick Houskeeper.**

For the trigonometrically minded, the exact formula is:

$$A = 2 \times \arctan(S/[2 \times F])$$

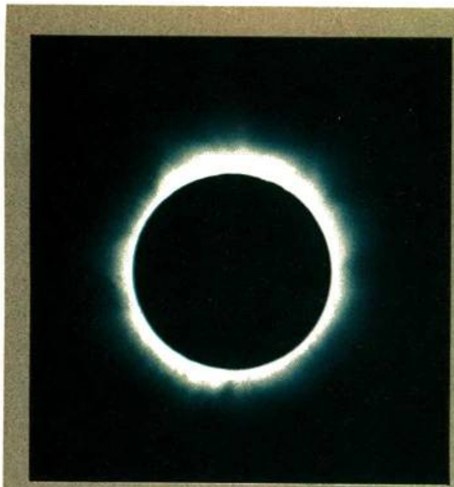
Lastly, consider this familiar formula:

$$d = F/f$$

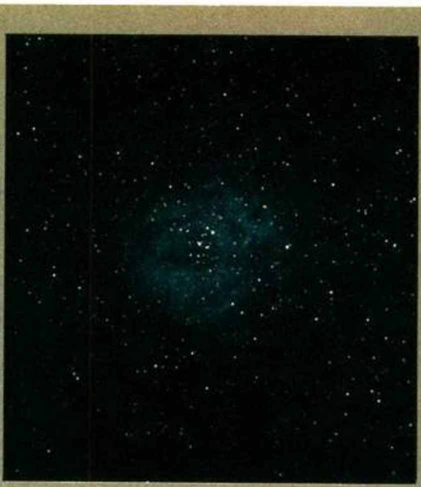
where d is aperture of the objective and f is the focal ratio. For a 135mm lens at f/3.5, the aperture is 135/3.5, or 38.6mm.

The 300mm Telephoto

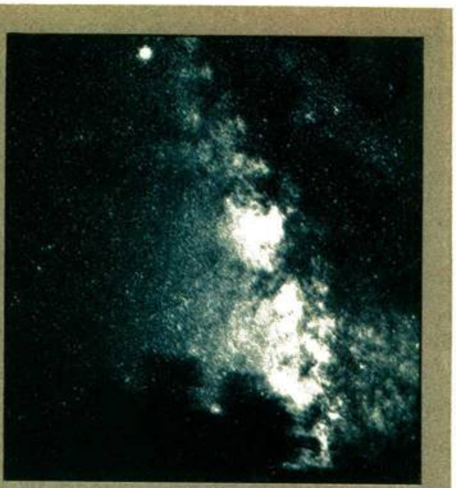
By 300mm, we really mean any lens between 250mm and 350mm and all



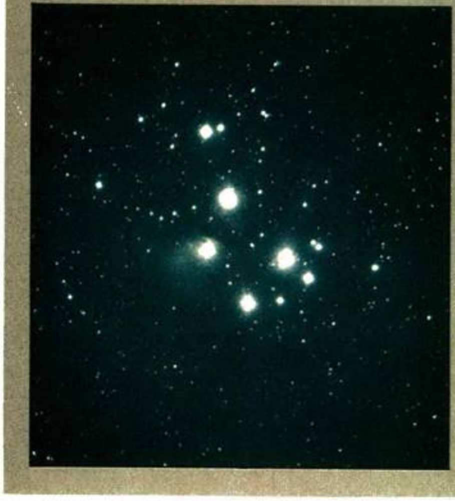
1000mm ⌂ Slow optics make deep-sky photography difficult, but those long lenses really reach out. With Fujichrome R100 film, Rick Dilsizian recorded the solar corona with an f/11 mirror lens and a ¼-second exposure.



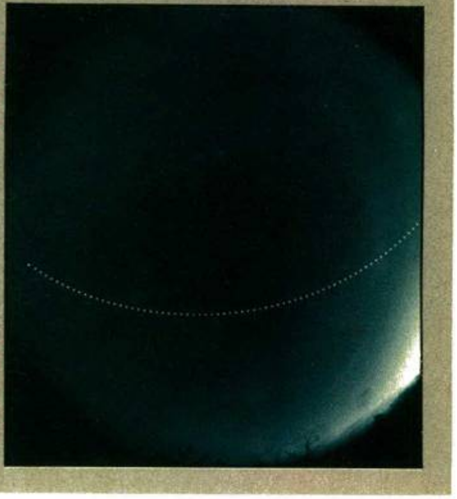
300mm ⌂ To bring out the Rosette Nebula, David Healy used a #92 red filter with his 300mm f/4 lens for this 15-minute exposure on Kodak 103a-E film.



28mm ⌂ Wide-angle lenses capture more sky. This 20-minute exposure with a 28mm f/2.5 lens on Kodak 103a-F film dramatically reveals a broad band of Milky Way. The bright star is Altair. Photo by Steve Reed.



500mm ◁ Spanning a bit less than half the frame, this picture of the Pleiades star cluster required a 15-minute exposure on Kodak 103a-O film with a lens opening of f/4.



7.5mm ▷ Multiple exposures with a fish-eye lens show the Moon as it moves across the sky. Astrophotographer Joseph Lofreddo used an intervalometer to fire the camera's shutter eighty times that night.

focal lengths in the same general ballpark. What we're talking about here is a "medium-long" telephoto lens.

An honest-to-goodness 300mm telephoto lens covers a sky area 4.6° by 6.9°. Orion's Belt will fit across the vertical dimension and the Hyades will just cover the horizontal dimension of 35mm film. Lenses in this class are good for exploring all the neat little nebulae and clusters along the Milky Way that normal lenses show as faint blobs of light. And consider this: those 8-inch f/1.5 Schmidt cameras you've heard about have a focal length of 300mm. Telephoto lenses are the poor man's Schmidt camera.

The average 300mm lens opens to f/5.6. This means it has an aperture of 54mm and can gather enough light to show stars down to magnitude 7.6 in a 1-minute exposure. With a lens this size, the Pleiades spans a whopping 10.5mm on film!

Before we get any deeper into our discussion, it's time for a word about f/ratios. Lenses with small f/ratios are called "fast" because the exposure times are short. Lenses with large f/ratios are called "slow." The exposure time for extended objects — nebulae, the Milky Way, and everyday terrestrial subjects — increases by the square of the focal ratio. That's why the f/3.5 lens we mentioned earlier takes six times as long to record the same sky background as an f/1.4 lens does. And that's why Schmidt cameras are so nice. They're fast.

The all-time handiest formula for figuring astronomical exposures incorporates this focal-ratio-squared rule:

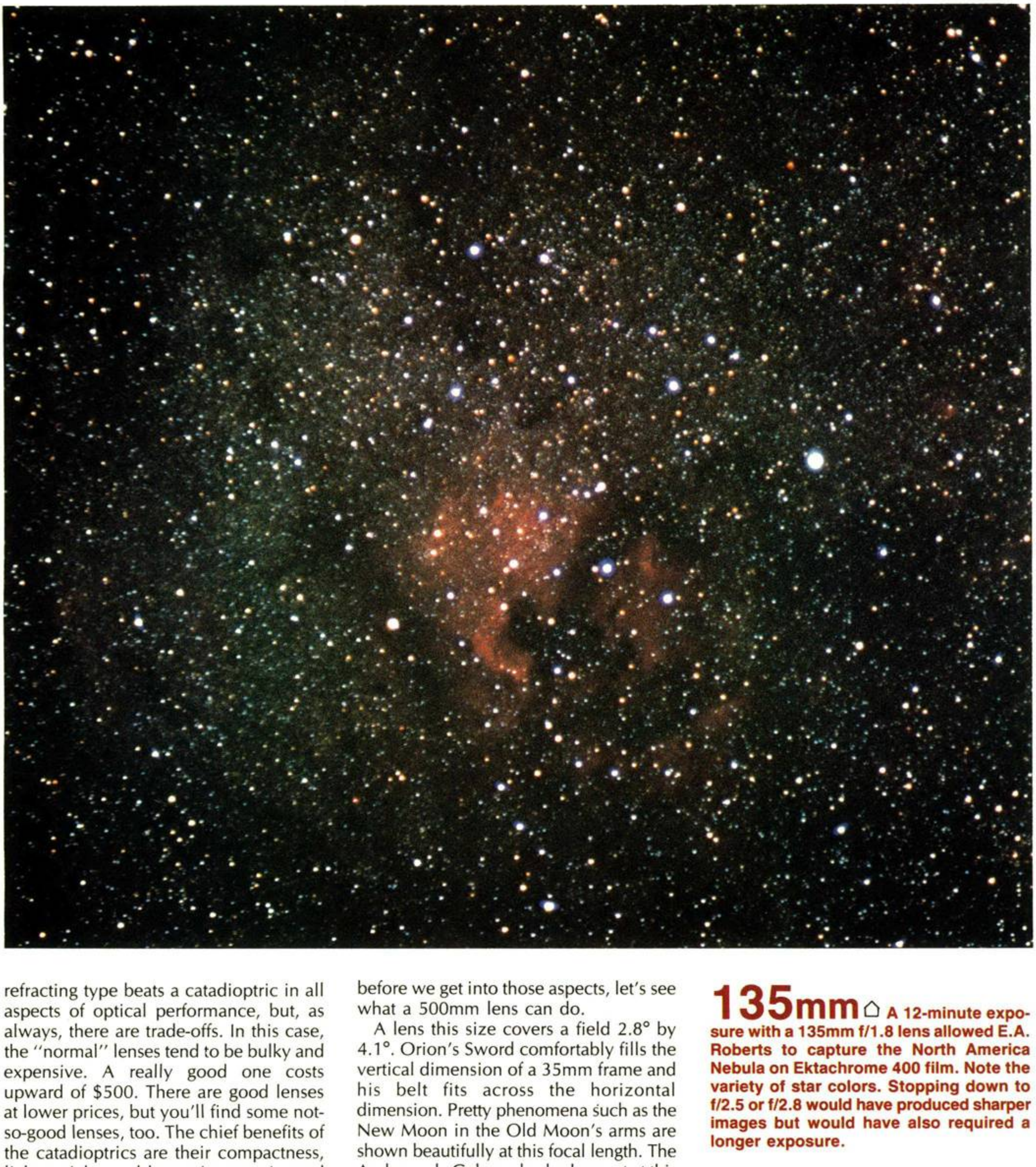
$$E = f^2/(S \times B)$$

where E is seconds of exposure, f is the focal ratio, S is film speed, and B is the extended object brightness index. (See "Exposure in Astrophotography," January 1985, for more on applying this useful formula.)

Remember, we're dealing with extended objects now. Consider this. A 2-minute exposure at f/1.4 is equivalent to a 32-minute exposure at f/5.6, and that's ignoring the effects of reciprocity failure in the film, which means the 32-minute exposure would have to be even longer. You can see now why it is a good idea to get a fast lens. It certainly helps keep the exposure times down.

The problem is that lenses become very expensive as the f/ratio drops, especially at longer focal lengths. For example, you can have your very own 280mm f/2.8 fluorite lens for about the price of a small car. Those nice 8-inch f/1.5 Schmidt cameras are less expensive — but you could still buy a used car for what they cost. The only solution is a compromise between your pocketbook and your patience for guiding long exposures.

You may see ads for catadioptric lenses, or "mirror-lenses" with a 300mm focal length. These are short and fat, and there is usually an obstruction in the front supporting the secondary mirror. In this focal length, a quality telephoto lens of the



refracting type beats a catadioptric in all aspects of optical performance, but, as always, there are trade-offs. In this case, the "normal" lenses tend to be bulky and expensive. A really good one costs upward of $500. There are good lenses at lower prices, but you'll find some not-so-good lenses, too. The chief benefits of the catadioptrics are their compactness, light weight, and low price tag. A good 300mm catadioptric lens will cost you $200 or more.

The 500mm Telephoto

Stepping up to a 500mm lens is a giant leap for an amateur astrophotographer. Though most 500mm lenses are considerably shorter than the 20 inches their focal length implies, they're still BIG. They may weigh upwards of 5 pounds. Purchasing one can run you into real money — at least purchasing one that's faster than those $79.95, 500mm f/8, "girl-watcher" lenses. Catadioptrics make a lot more sense at 500mm focal length, and their performance is better, to boot. But before we get into those aspects, let's see what a 500mm lens can do.

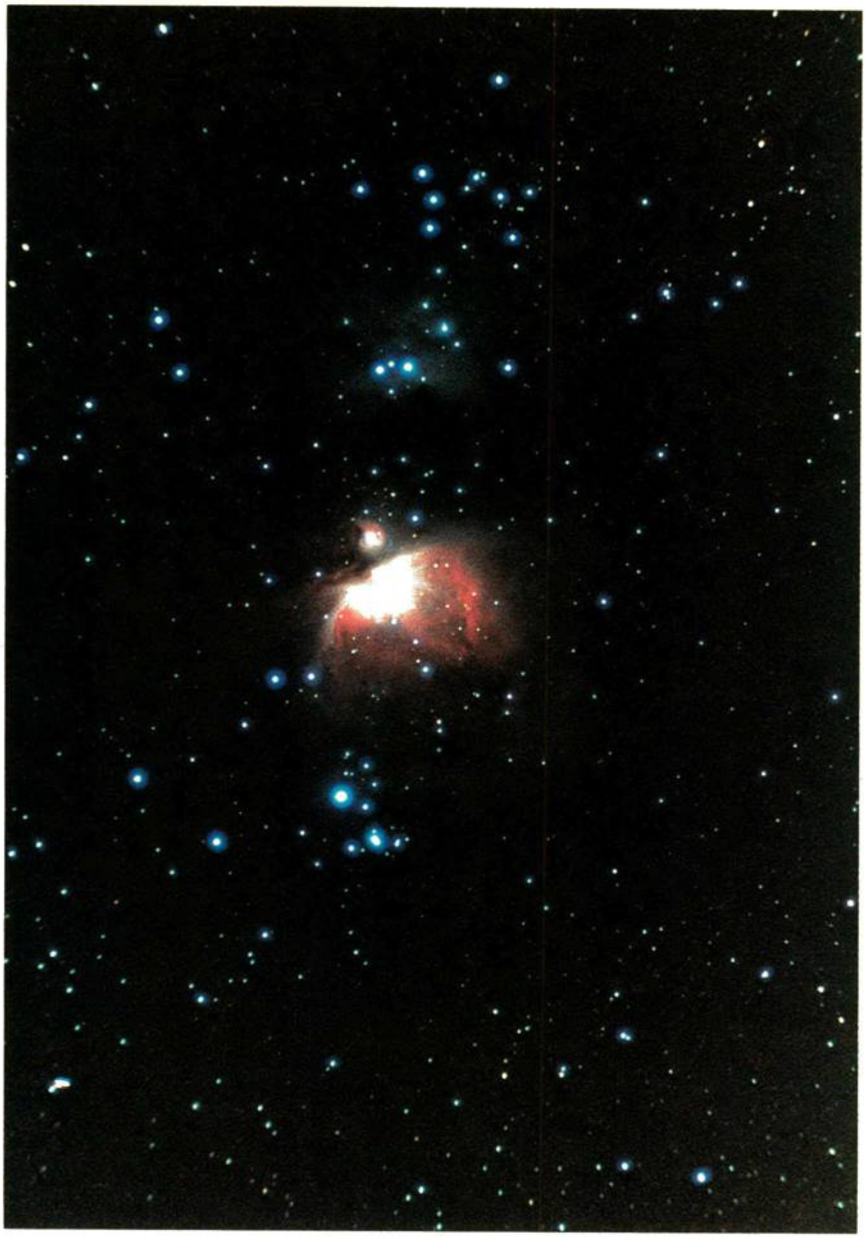
A lens this size covers a field 2.8° by 4.1°. Orion's Sword comfortably fills the vertical dimension of a 35mm frame and his belt fits across the horizontal dimension. Pretty phenomena such as the New Moon in the Old Moon's arms are shown beautifully at this focal length. The Andromeda Galaxy also looks great at this image scale.

A 500mm f/8 "tele-lens" boasts an aperture of 62.5mm, which will record stars to magnitude 8.0 in 1 minute. The Pleiades will appear 17.5mm across, but you'd have to guide for a long time — typically 30 minutes at f/8 on fast color slide film — to record much of the nebulosity around Merope.

At this point, you may want to look at a more astronomically oriented system, like a Schmidt-Newtonian telescope. It may not look much like a "lens" to you, but it acts like one, and a 5.5-inch aperture f/3.6 Schmidt-Newtonian has a 500mm focal length. An advantage of these "telescope" lenses is their ability to record faint stars quickly. In 1 minute, a 5.5-inch puts well-exposed images of stars down to magnitude 9.9 on your film. You can expect to spend $500 or more for a 6-inch Schmidt-Newtonian.

135mm ⌂ **A 12-minute exposure with a 135mm f/1.8 lens allowed E.A. Roberts to capture the North America Nebula on Ektachrome 400 film. Note the variety of star colors. Stopping down to f/2.5 or f/2.8 would have produced sharper images but would have also required a longer exposure.**

If, however, you want to stick with camera lenses, let's look at the options. At the 500mm focal length, catadioptric lenses usually have focal ratios of f/5.6 or higher. Prices start at $500 and decrease as the f/ratio increases. Telescope manufacturers have gotten into this field



629mm ◁ **Using a 629mm f/5.1 telephoto lens with Fujicolor HR1600 film, Bryan Wallace recorded the full glory of the Orion Nebula, including the faint outer loop of nebulosity and blue M-43. The full 35mm frame is shown here with north at the top. The exposure was only 4 minutes and 48 seconds.**

in the last few years. Telephoto lenses of this focal length don't commonly open up wider than f/8, but half-hour-long exposures may not frighten you.

The 1000mm Telephoto

The step from a 500mm focal-length lens to 1000mm focal length is another big one. On 35mm film, these big lenses have a field 1.4° by 2.1° and give an image scale equivalent to that at the prime focus of an 8-inch f/5 Newtonian scope or an 8-inch SCT with a focal reducer.

At f/10, a speed common for lenses of this length, the system has an aperture of 100mm, or 3.9 *inches*. Stars down to magnitude 9.0 will be recorded in 1 minute. The Pleiades Cluster fills the 35mm film frame. But at f/10, you're stuck with hour-long exposures before you can record nebulosity, although the new modern super-fast hypered films show some promise of reducing this.

The "super-teles" are great for recording solar and lunar eclipses, unusually close planetary conjunctions, and other relatively bright sky events. They are slow for deep-sky work but not hopelessly so. Of course, about 15 minutes into a 60-minute exposure with an f/10 lens will make you start to wonder whether an 8-inch f/5 Newtonian reflector might not be better.

Refracting lenses this long are very difficult to find because the demand for them is small. Who wants to lug around a 3-foot-long 20-pound lens you'd have to rob a bank to pay for?

Fortunately, there are lots of catadioptric lenses on the market in the 1000mm focal-length class. Although their focal ratios are commonly f/10 or higher — hardly prime material for astrophotography — for $600 or thereabouts you can have a good 1000mm f/8 mirror lens; for under $400 you can find a slower one.

Zoom Lenses

If you can find a truly sharp zoom lens, more power to you. Most zooms aren't as sharp or as fast as single-focal-length lenses. That's not to say there aren't any, but merely that it's hard to find them. Zooms also tend to suffer from "zoom creep" during long exposures, as gravity slo-o-owly pulls the movable elements of the lens earthward. While this effect may be interesting, you probably don't want it to happen to your astrophotos.

Which Lens Is Best?

Actually, the question should be: which lens is best *for what you want to do*? Each type of lens has its own strengths and weaknesses. Start by figuring out what you want to photograph first, then pick the type of lens that can best do the job.

Remember, too, that just because a certain lens is not perfect for astrophotography doesn't mean that you shouldn't buy it. If you have an interest in terrestrial photography, then factors like the f/ratio may not be all important. Sky pictures that were impossible a few years ago — with yesteryear's 400 ISO films — now fall within the realm of the possible with today's 1600 ISO films.

In the end, the decision to buy really comes down to two questions: Can you afford it, and will you use it enough to justify buying it? Consider these questions carefully. If you can honestly answer yes to both, then go ahead and get the lens you want. Don't settle for the first lens you see; go to different stores and look at a variety of lenses. Check their construction and, if possible, get a look through them. You may decide you don't want the lens you thought you did, or that you want a different one.

If you're on good terms with your camera store, explain that you want the lens for star pictures, and that its star images have to be sharp all the way to the edge of the frame. Then ask whether you can "test drive" the lens you're interested in. If the store is not willing to let you walk out the door with an expensive lens, ask if they'll let you purchase with the right to return it if it "isn't right" — but be sure you get such a promise in writing on the sales slip. Naturally, you can't expect any store to honor such an agreement if you keep the lens for three months and return it in damaged condition, so treat it *very carefully* when you test it. If a store won't go for such an arrangement, look for the same lens somewhere else.

Picking camera lenses for astrophotography isn't as difficult as it may seem. Just keep in mind what you want to do with your new lens, then choose it carefully so when you finally bring it home, you'll have a precision optic that you can use and enjoy for years to come.

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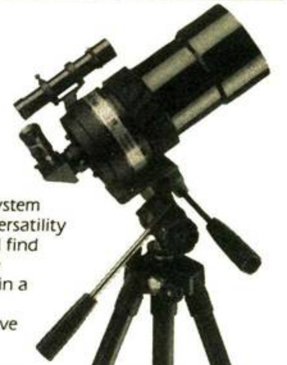

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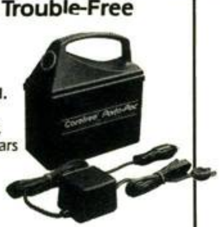

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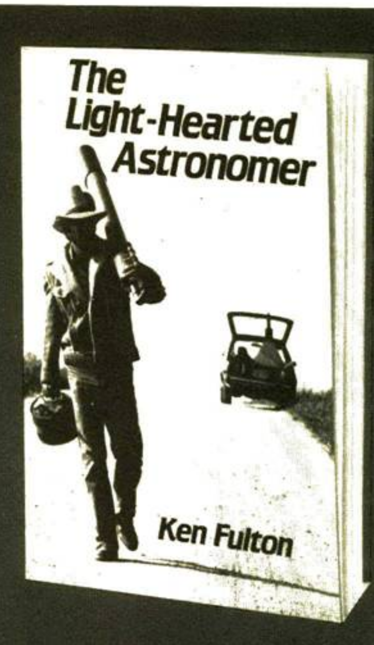

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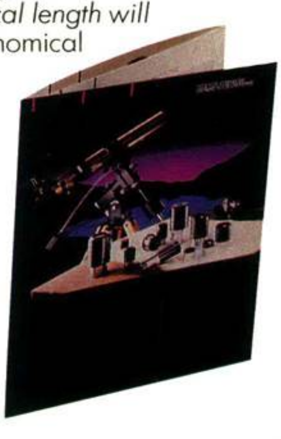

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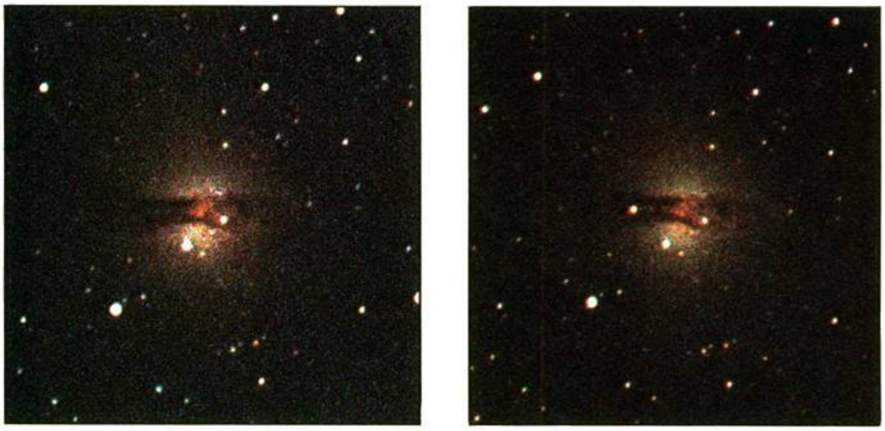

The supernova's position in the middle-left of the dust band is evident in these photos taken on January 8, 1986 (left) and May 10, 1986 (right), seven days after its discovery. Photos were taken using a 12-inch f/5 and a 15-minute exposure on standard Konica 1600 film by Jim Riffle.

Supernova Places Centaurus A Nearer Than Estimated

Observations of a supernova in the peculiar galaxy NGC-5128, also known as radio source Centaurus A, indicate that the galaxy is much closer than was previously estimated and, in fact, may be an extreme outlying member of the Local Group. The previous minimum distance accepted was on the order of 5 megaparsecs. However, the revised distance based on the luminosity of the supernova is between 2 and 3 megaparsecs (7 to 10 million light-years).

The supernova, designated 1986G, was discovered May 3 by Australian observer Rev. Robert Evans of Hazelbook, New South Wales. It has an apparent position southeast of the center of the galaxy, practically in the middle of the dark dust lane.

Spectra obtained from May 5 to May 7 by J. Tonry and M. Strauss of the Cerro Tololo Interamerican Observatory in La Serena, Chile, revealed that the supernova was of Type I and was approaching maximum energy output. However, subsequent observations made May 11 showed that the star was continuing to brighten at a rate of about 0.05 magnitudes per day. The visual magnitude derived on that day was 11.4, whereas it was 11.6 on May 8 and 11.7 on May 7.

These observations also placed the supernova's true position well inside the dusty galaxy, and as a result was estimated to be dimmed by about 4 magnitudes. Astronomers from the European Southern Observatory in La Silla, Chile, believe that had the star been located in an unobstructed region, it would have brightened to magnitude 7.5, making it the brightest supernova of this century.

Type I supernovae are thought to be the result of thermonuclear reactions in a white dwarf that has accreted more than 1.4 solar masses worth of matter from its companion star. They are characterized by remarkably similar light curves and usually peak at an absolute magnitude of about −19. These factors make Type I supernovae excellent distance indicators.

Only about twenty to twenty-five supernovae are detected per year in other galaxies. The last one that appeared in our galaxy was discovered by Johann Kepler in 1604. No supernovae had been detected in Centaurus A before 1986G.

New Study Questions Expanding Universe

The expansion of the universe has become such a widely accepted idea that most people are surprised to learn that not all astronomers are convinced of its validity. Although most astronomers interpret galactic redshifts as a Doppler effect caused by their recession from Earth, a few researchers believe the observations can be better explained by theories other than an expanding universe.

Writing in the February 15, 1986, issue of *Astrophysical Journal*, Paul LaViolette presents evidence that the "tired-light" theory is superior to that of an expanding universe in describing the observed redshifts of distant galaxies. Originally proposed in 1929 by Fritz Zwicky, a Swiss-born astronomer working at the California Institute of Technology, the tired-light model postulates that photons continuously lose energy as they travel through space. Since the light from more distant objects travels farther to reach us, it suffers a greater energy loss and is therefore shifted more toward the red end of the spectrum.

LaViolette compared the tired-light cosmology to the standard model of an expanding universe on four different observational tests and has found that on each one the tired-light hypothesis was superior. The differences between the rival cosmologies are most apparent at large redshifts, however, and it is in this region that observations are most difficult to make. Future observations with the Hubble Space Telescope and ground-based CCD cameras should be able to extend the data set out to larger redshifts, offering hope of clarifying this important debate.

Largest Gravitational Lens Sighted

The most massive gravitational lens yet found has been detected by a group of astronomers led by Edwin Turner of Princeton University. Conventional explanations may not be adequate to describe this object, which is over 400 times more massive than the largest previously known lens.

First predicted by Albert Einstein as a consequence of his general theory of relativity, gravitational lenses result from a large gravitational field deflecting light from a more distant object so the light appears to be coming from more than one direction.

The first gravitational lens was discovered in 1979. It consisted of two quasar images with identical redshifts and spectra, leading astronomers to conclude that it was actually two images of the same object. When a rich cluster of galaxies was later found along the same line of sight, the gravitational lens interpretation became accepted. Seven other gravita-

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tional lenses have been found since then.

Results of this current work are reported in the May 8 issue of *Nature*. Joining Turner on the project were Donald Schneider of the Institute for Advanced Study, James Gunn of Princeton, Bernard Burke, Jacqueline Hewitt, and Glen Langston of MIT, and Charles Lawrence and Maarten Schmidt of Cal Tech.

The area being studied, which lies in a region of high quasar density, had been mentioned earlier this year as a possible gravitational lens by Princeton astronomer Bohdan Paczynski. The authors obtained detailed spectra of the two quasar images in March with the 4-meter telescope at Kitt Peak. The spectra were remarkably similar in appearance and had indistinguishable redshifts, leading to the gravitational lens interpretation.

The remarkable aspect of this system is the separation of 157 arcseconds between the two images — more than twenty times greater than the largest previous gravitational lens separation.

Although the precise nature of the lens is not apparent, the authors suggest three possibilities: an extremely rich cluster of galaxies, a supermassive black hole of 1,000 trillion solar masses, or a cosmic string. Cosmic strings are theoretically predicted, one-dimensional objects that may have been produced during a phase transition in the early universe.

Regardless of the cause, the researchers feel more observations should be made in this region of sky. With the properties exhibited by this lens, it is quite possible that some of the other quasars in this field could also have multiple images. If such images are found, they could help to model the mass distribution of the lens.

EXOSAT Mission Ends

After an attitude control system malfunctioned, sending the European X-ray Observatory Satellite (EXOSAT) into an uncontrollable spin, it was virtually all over for the successful spacecraft that had made over 2,000 observations of cosmic x-ray sources.

Attempts by engineers from the European Space Operations Center in West Germany to correct the spin were unsuccessful. With its supply of hydrazine attitude control gas spent, ESA officials had predicted that EXOSAT would re-enter the atmosphere and burn up on May 6. But by mid-May the 400-kilogram satellite was still in orbit.

Launched on May 26, 1983, EXOSAT exceeded astronomers' expectations by yielding new data on x-rays emitted by the entire range of astronomical objects — from planets, stars, and supernovae to quasars, neutron stars, black holes, and active galactic nuclei. The satellite was operated as an observatory and was utilized by astronomers the world over. Results are still being published in scientific journals and presented at astronomical conferences. In fact, it is expected that the entire EXOSAT database will take years for scientists to analyze.

Significant discoveries by EXOSAT include the shortest variability periods ever detected for x-ray sources (found flickering in the cores of some distant galaxies) and several instances of "quasi-periodic oscillations" in x-rays being emitted by hot material orbiting close to the surface of several neutron stars.

EXOSAT was originally scheduled to conclude its mission in May 1985. However, because of the satellite's many successes and the flood of new scientific data that followed, the ESA member states approved an extension. It had been hoped that the on-board hydrazine thrust system could stabilize the orbit until the latter part of 1986.

New Survey Shows Negligible Galaxy Evolution

A major new survey of galaxies by Donald Hamilton of the National Optical Astronomy Observatories suggests that galaxies do not evolve as rapidly as most astronomers have thought. From his results, Hamilton has been able to place constraints on some of the fundamental constants of the expanding universe.

Astronomers expect the light from galaxies to change as the stars within them grow older. As any stellar population ages, its color shifts toward the red end of the spectrum. This effect is easiest to see in open and globular clusters in our own Milky Way, where the entire population of an individual cluster was formed at the same time. In the youngest clusters, the predominant source of light comes from hot, blue stars. However, since these are also the most massive stars, they evolve the fastest. As a result, the contribution of red giant and supergiant stars to the total light becomes most significant as the cluster ages.

The same type of spectral evolution should also be observable in galaxies. Although all galaxies are believed to have formed at approximately the same time, the light we receive from distant galaxies takes longer to reach us, and so we see them at earlier stages in their history. By surveying galaxies at varying distances, Hamilton has shown that the observed spectral changes are less than predicted.

Hamilton restricted his study to giant elliptical galaxies because these galaxies — and giant ellipticals in particular — are presumed to have produced stars in a single burst during their initial collapse. Spiral galaxies, in contrast, continuously form new generations of stars from gas and dust, which would confound such an analysis.

To get a sufficient number of galaxies that met the selection criteria of his project — giant elliptical galaxies within 3 arcminutes of a sufficiently bright star (to

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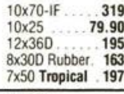

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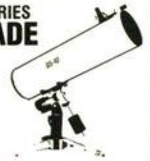

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ensure accurate positional offsetting of the telescope) over a large range of redshifts — Hamilton needed to conduct a new galaxy survey. The survey, conducted with the 4-meter telescopes at Kitt Peak and Cerro Tololo, covered about 7 square degrees of sky and yielded a total of nearly 300,000 galaxies to a blue magnitude of 24. From these, Hamilton chose twenty-six galaxies that met his criteria at redshifts corresponding to distances of about 800 million to 8 billion light-years. He subjected each of these to further spectrophotometric analysis to accurately determine the color of each galaxy.

The most important result of this work is the seeming lack of any significant galaxy evolution. Where conventional theory predicted noticeable evolutionary effects at comparatively low redshifts, Hamilton found little if any difference between galaxies out to the limits of his survey. The survey also confirmed that all of these galaxies formed within 2 billion years of each other.

In combination with current models of spectral evolution, the data suggest that giant elliptical galaxies are much older than 8 billion years and are consistent with an estimated age of 16 billion years. The data are also consistent with a Hubble constant of 50 kilometers per second per megaparsec with little deceleration in the universal expansion caused by gravitational effects, implying that the universe is most likely "open" and will continue to expand forever.

New Milky Way Is 30 Percent Smaller

A group of researchers has discovered that the Sun is much closer to the center of the Milky Way Galaxy than astronomers previously thought. The results imply that our galaxy is also about 30 percent smaller than the accepted value.

Mark Reid of the Smithsonian Astrophysical Observatory presented these results in a talk to the National Science Foundation. He was joined in this project by Matthew Schneps, James Moran, and Carl Gwinn, also of the Smithsonian Observatory, Reinhard Genzel of the University of California at Berkeley, Dennis Downes of the Institute for Millimeter Wavelength Radio Astronomy in Grenoble, France, and Bernt Ronnang of the Onsala Space Observatory in Sweden.

The technique used in this new study was made possible by the discovery of a region of newly formed stars near the galactic center. Surrounding this region, designated Sagittarius B2 North, is a rapidly expanding cloud of gas and dust, and at the outer edge of this are several water masers, which are objects that emit radio frequency radiation at a specific wavelength characteristic of water molecules.

The astronomers measured the motion of these masers as the cloud expanded. The radial, or line of sight, motions of the sources were found directly from the Doppler effect, and their lateral motions were determined by interferometry with radio telescopes in New Mexico, West Virginia, Massachusetts, and California. Combining the two results enabled the researchers to accurately determine the distance to the expanding cloud.

Earlier determinations of our distance from the galactic center were based on the study of globular clusters. These objects are spherically distributed around the center of the Galaxy and can therefore be used to locate the center's position. The distance can then be found if the distances to the clusters are known, and these are estimated from the luminosities of RR Lyrae variables in the clusters.

The new figures place the Sun approximately 7,000 parsecs from the center of the Milky Way; the previously accepted value was 10,000 parsecs. There is a corresponding decrease in the size of the disk component of the Galaxy, from roughly 30,000 parsecs to 21,000 parsecs.

This new geometric technique also promises to have an impact on other areas of astronomy, including the estimated size of the universe. University of Texas astronomer Gerard de Vaucouleurs has been at the forefront of using the Milky Way as a standard for comparison with other galaxies. Shrinking the scale of our galaxy means that distances to some galaxies will have to be reduced correspondingly.

ASTRONOMY
AstroCalendar

July 31-August 4
3rd Annual Mount Kobau Star Party (superb observing, telescope-making and astrophotography contests, speakers), Okanagan Valley, British Columbia. Contact: Peter Kuzel, 4100 25th Ave., Vernon, B.C., Canada V1T 1P4. Phone (604) 545-1226.

August 2
Stellafane, Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Rd., Sudbury, MA 01776.

August 5-10
ASTRO CON 86 (national convention of the Astronomical League), Baltimore, Maryland. Contact: ASTRO CON 86, 642 Kingston Rd., Baltimore, MD 21220.

August 8-10
STARFEST '86 (fifth annual observing convention of the North York Astronomical Association), River Place Campground, Mount Forest, Ontario, Canada. Contact: Andreas Gada, 145 St. George St., Apt. 701, Toronto, Ontario, Canada M5R 2M1.

August 10-12
Star Trails West (2-day class), Yellowstone National Park, Wyoming. Contact: Gene Ball, Yellowstone Institute, P.O. Box 117, Yellowstone National Park, WY 82190. Phone (307) 344-7381 ext. 2384.

September 5-7
ASTROFEST (sponsored by the Chicago Astronomical Society), Camp Shaw-Waw-Nas-See Campsite, Illinois. Contact: Astrofest, P.O. Box 596-A, Tinley Park, IL 60477. Phone James Hansley, Chairman, (312) 764-5131.

October 2-5
Okie-Tex Star Party (sponsored by the Oklahoma City Astronomy Club), Lake Murray, Oklahoma. Contact: Joe Pearson, 700 Teal Place, Edmond, OK 73034.

October 10-12
Pacific Planetarium Association Fall Meeting, Salem, Oregon. Contact: Tom McDonough, Chemeketa Community College, 4000 Lancaster Dr. NE, P.O. Box 14007, Salem OR 97309. Phone (503) 399-5161.

October 24-26
8th Annual Astronomy Jamboree, Custer Institute, Southold, Long Island, New York. Contact: Tom Carey, Vanderbilt Planetarium, Centerport, NY 11721. Phone (516) 757-7502.

October 25
Telescope Users Clinic, Whittier College, Whittier, California. Contact: Bob Ferguson, Western Observatorium, 13215 E. Penn St., Suite 411, Whittier, CA 90602. Phone (818) 795-4181.

October 31-November 2
Deep South Regional Stargaze, Percy Quin State Park, McComb, Mississippi. Contact: Frank W. Loflin II, ALCOR, Jackson Astronomical Association, 280 W. Lorenz Blvd., Jackson, MS 39213. Phone (601) 982-2388 days or (601) 856-3636 evenings.

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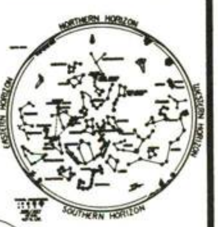

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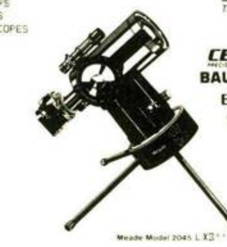

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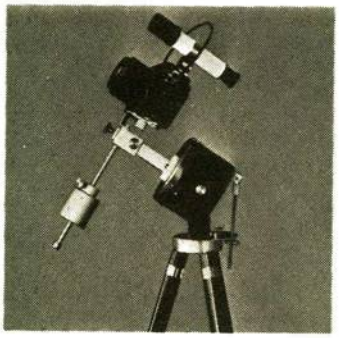

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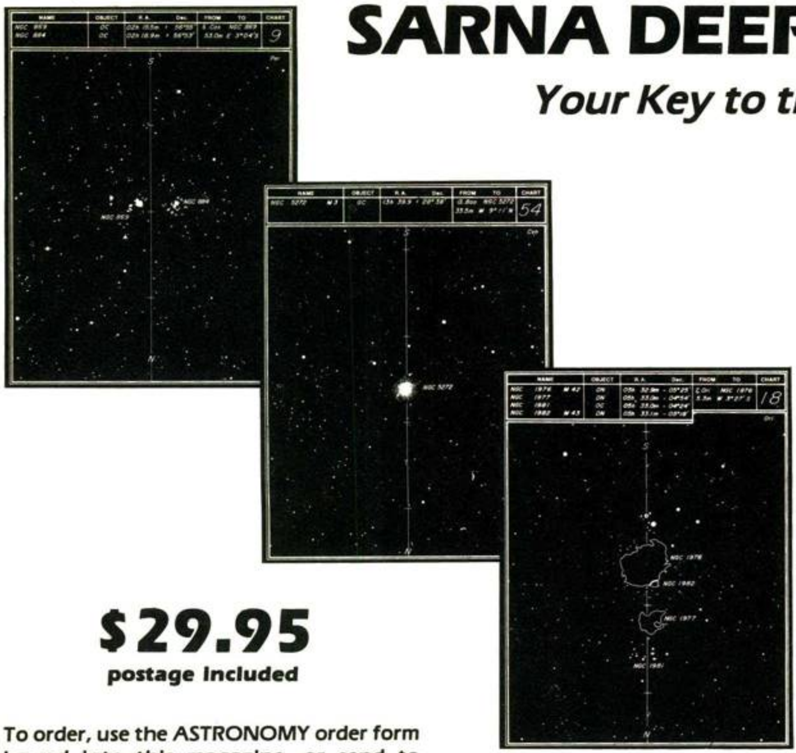

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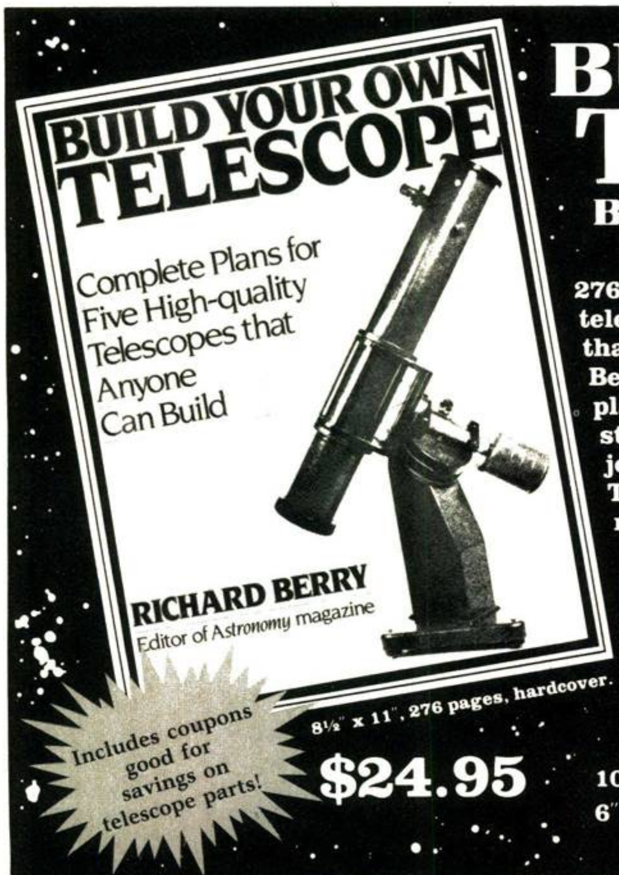
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by Claude J. Bauer

In the late 1980s, a unique NASA spacecraft christened the Cosmic Background Explorer (COBE) will be launched from the Space Shuttle into a 900-kilometer sun-synchronous orbit around the Earth. COBE's mission will be to conduct a series of experiments aimed at gathering information on the castaclysmic event that many believe gave birth to our universe — the Big Bang.

COBE is one of the largest space observatories ever built, weighing in at 10,000 pounds and standing 15 feet tall. The COBE project is at the forefront of space exploration, and the three highly specialized instruments COBE will carry promise to provide astronomers with long-awaited data on the great primeval explosion.

COBE's tour of duty will last one year, during which it will look for the 3-degrees Kelvin cosmic background radiation (CBR), the remnant of the radiation content of the primordial fireball that created the universe. The CBR is as close to a fossil as an astronomer is likey to come across in that it carries the signature of an event that occurred 15 billion years ago. This "fossil of radiation" is so extraordinarily faint — hundred of millions of times fainter than the heat produced by a kitchen match — that only state-of-the-art instrumentation can detect it.

Dr. John Mather, COBE project scientist and principal investigator of the Far Infrared Absolute Spectrophotometer (FIRAS), one of three COBE instrument packages, says that "we will be able to see the swirling, turbulent motions of the materials of the early universe, and actually . . . show [COBE's maps] as photographs of that period."

One of COBE's top priorities is to find out if the CBR's spectrum — the distribution of its intensity as a function of its wavelength — is identical to that of a "black body" spectrum at 2.7 degrees Kelvin, the temperature expected if the CBR has only cooled since its last interaction with matter.

"This information is important," says Mather, "because the spectrum is extremely old and bears traces of everything that has occurred since the universe was a million times smaller and a million times hotter." The FIRAS instrument is designed to measure this elusive radiation.

COBE's second experiment will measure the CBR's angular distribution — the degree to which it varies across the sky. Dr. George Smoot of the University of California is the principal investigator for COBE's Differential Microwave Radiometer (DMR) experiment. Smoot explains that after the Big Bang, the CBR and primordial matter interacted through a series of scatterings of photons off free electrons. The last time the bulk of the CBR interacted with primordial matter was at a distance corresponding to a redshift of about 1,000 or greater.

"When you measure the angular distribution, you are measuring what the surface of the universe looked like at the time of the last scattering," says Smoot. "With COBE, we are trying to make the measurements on a large angular scale. The beam width of the two antennas is about 7 degrees, and the whole sky is about 40,000 square degrees," which means that scientists will have about 1,000 pixels, or points in the sky, to examine. "You have to cover the whole sky because distortions can be fairly localized."

COBE's third instrument package — the Diffuse Infrared Background Experiment (DIRBE) — may well reveal more surprises than either of the other experiments.

For example, many astronomers think the universe is like a giant balloon filled with matter — galaxies, stars, and solar systems — that has been inflating for 15 billion years. Some believe the gravitational pull of the universe on itself might be enough to stop the expansion, at which point the universe will begin to collapse upon itself. The one problem with this theory is that scientists have not been able to locate enough mass to "close" the universe. Consequently, they are hoping the DIRBE will find the missing matter they need, as Mather says, "to complete the budget of the universe."

"If there are objects that are cool but not completely dark," he adds, "then the radiation they emit will be detectable by the DIRBE and FIRAS instruments. If we find more and more missing matter, we can add up the total and say, 'Yes, there is enough to stop the expansion.' And there really is a strong theoretical prejudice that says it should be there."

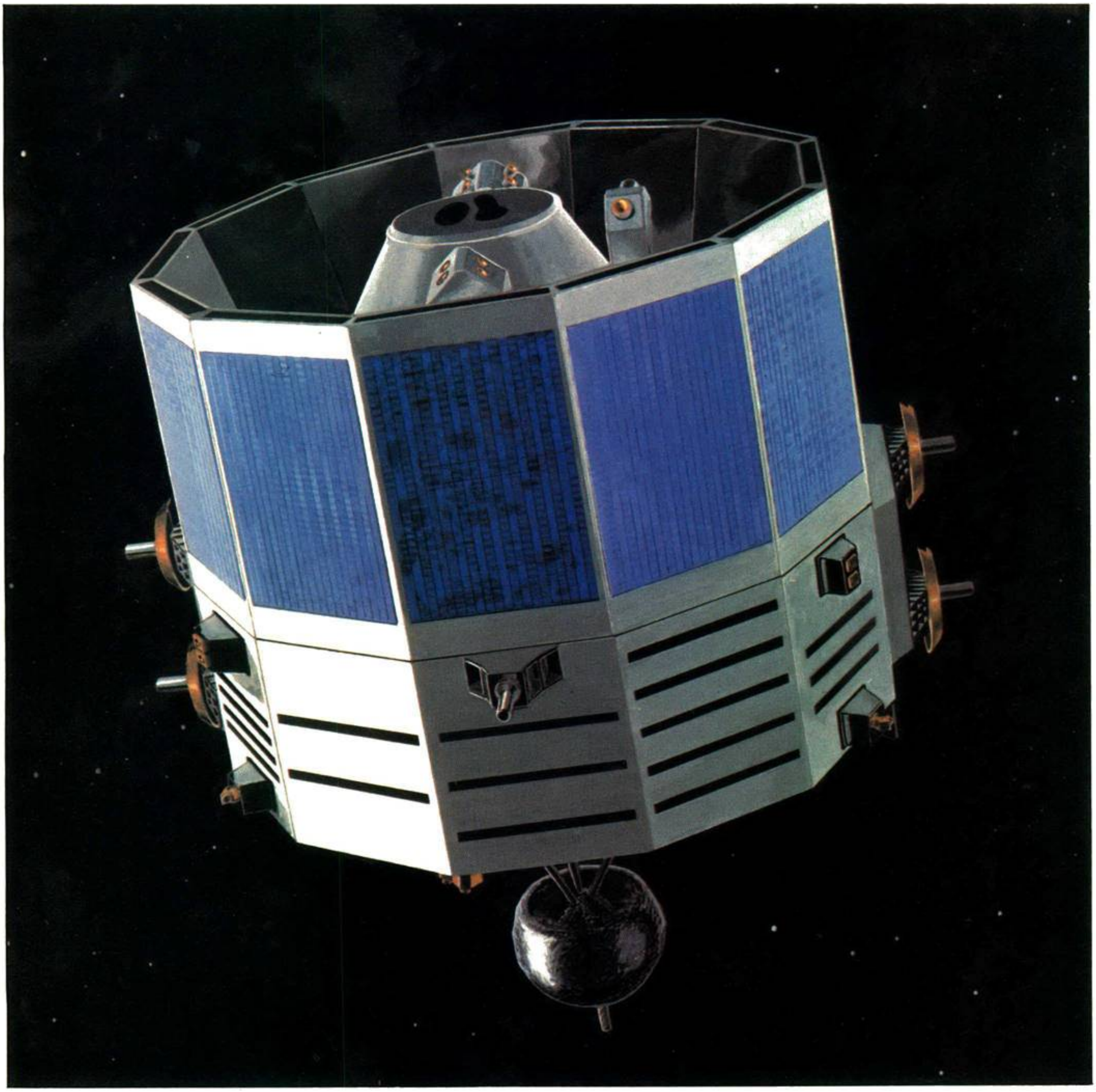
COBE's Game Plan

The Space Shuttle will put COBE into a 300-kilometer "parking orbit," from which it will boost itself into its permanent circular orbit of 900 kilometers at a 99-degree inclination to the equator. COBE's permanent orbit, identical to that of its predecessor IRAS, is unique in several respects. First, COBE will continuously skirt the twilight regions of the Earth to avoid radiation emitted by the Earth and Sun. Second, once in orbit, COBE's solar-panel clad hull will spin on its axis at 0.8 revolution per minute to keep the instruments pointing toward the heavens and away from Earth's cacophony of thermal light and radio interference. And, Smoot adds, spinning around its axis will help COBE maintain the accuracy of the instrumentation. Although both antennas on the DMR were made with extreme care, they may not be exactly identical.

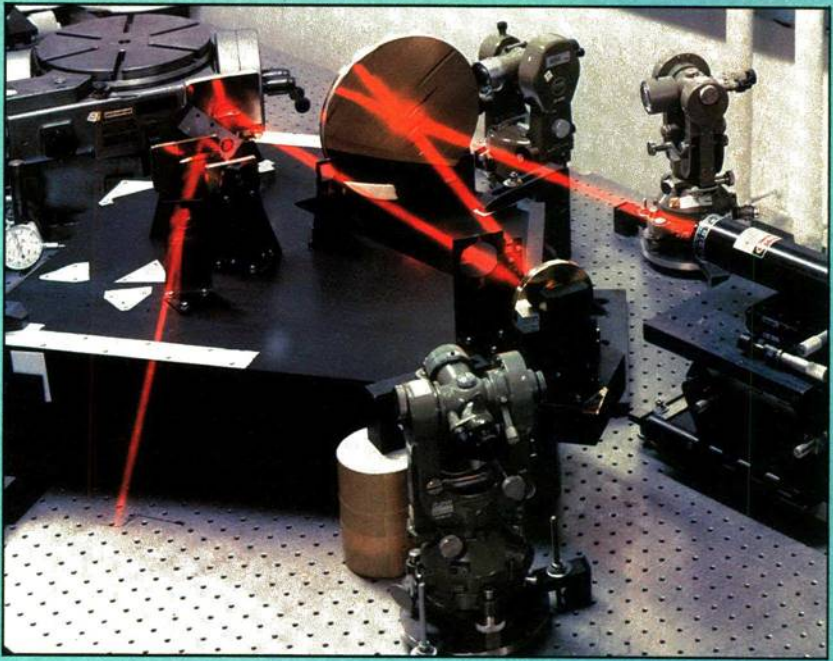
"We depend on the rotation of the spacecraft to interchange the antennas," says Smoot. "If you rotate the spacecraft around 180 degrees, the antenna that was looking at one part of the sky will be looking at the matching part of the sky on the other side; thus, the signal from the sky should reverse, and the signal from the instruments should stay constant. Also, the rotation can be used to distinguish between the signals coming from the sky and the signals coming from the instrument. Another advantage of the rotation of the spacecraft is that the instrument scans a circle in the sky as the spacecraft orbits around the Earth, and you get a lot of sky coverage that way."

NASA scientists hope COBE's data will help them

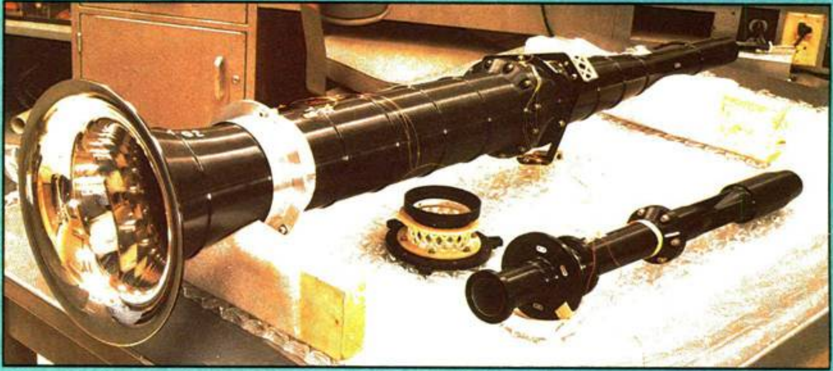
Artist's conception of the COBE spacecraft in orbit showing the globe-like data link antenna at the bottom, the Earth and Sun sensors mounted on the outer panels on both sides, the solar panel array, and partial views of the DMRs mounted in the opening at the top. All photos and illustrations courtesy of John Mather, Goddard Space Flight Center.



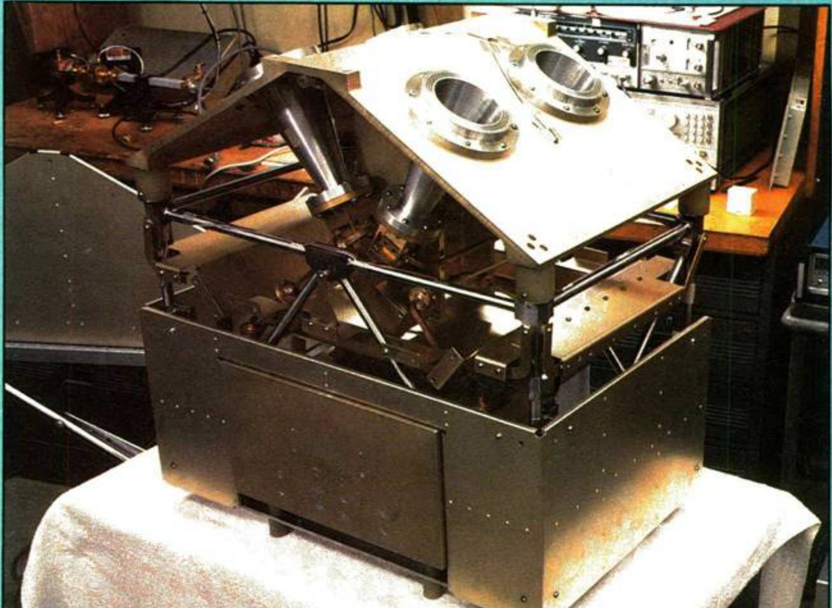
COBE's Instrument Package



A laser beam passes through part of the DIRBE optical configuration from the primary and secondary mirrors, through light stops, and finally reflecting off of the flat tertiary mirror.



The FIRAS skyhorn antenna and the smaller black body reference antenna.



The 53 GHz DMR showing the cone-shaped microwave antennas.

understand why the universe, born of such a cataclysmic event as the Big Bang, appears so uniform and whether or not the expansion was as uniform in the early universe as it appears now. But whether or not COBE confirms or destroys current theories is not as crucial as the data it will return. There is no telling what new theories may be spawned from scientists' analyses of COBE's data. "And that," says NASA program scientist Nancy Boggess, "is the excitement of research."

Until COBE, scientists have relied on CBR data collected by a variety of methods including high-altitude airplanes, balloon flights, and some ground-based observations. Clearly, infrared astronomy is better conducted in space away from the dispersing effects of the atmosphere. Observations made from high-altitude aircraft improve the situation somewhat but are still limited by short observing periods and radiation that is emitted and absorbed by the upper atmosphere, which confuses the readings. Boggess likens the process of reducing these readings to "putting together a jigsaw puzzle of a Cezanne without the blue and yellow pieces."

COBE's observations, which are expected to be up to one hundred times more accurate than those done from Earth, will be a boon to scientists who have already managed to measure the distribution of the CBR with amazing accuracy. Previous studies have shown that the CBR is distributed uniformly over the heavens to within one tenth of 1 percent. This slight variation, or anisotropy, is attributed to the solar system's orbit around the center of the galaxy as well as the motion of our galaxy through the universe. The anisotropic variation is characterized by a "cool" spot in the radiation from the constellation Aquarius and a somewhat "hotter" spot in the constellation Leo. Dr. Boggess predicts, "If we don't find any anisotropy on that scale, it is going to be exceedingly exciting because theoreticians will have to come up with an new explanation for its absence."

Since the discovery of the CBR twenty-two years ago, the body of knowledge surrounding this phenomenon has advanced to the point where scientists are preoccupied with a variation in its distribution of one tenth of 1 percent. But the detective story that led to the discovery of the CBR involved dozens of astronomers and photographers.

The Beginning of the Universe

By the 1900s, after centuries of religious and secular controversy, it was well established that Earth was not the center of the universe, nor even of the solar system, and that it was moving.

V.M. Slipher was one of the first astronomers to discover that, with the exception of the Andromeda Galaxy, the spectra of the light from distant spiral galaxies was shifted toward the red end of the spectrum. Slipher's discovery destroyed the complacent notion of a static universe and showed instead that nearly every galaxy was receding from Earth, many at velocities up to millions of kilometers per hour.

In 1917, Willem de Sitter argued that Einstein's general theory of relativity could be used to show that the universe was continuously expanding. By 1927, astronomer Georges Lemaitre proposed a theory of creation not unlike that of the Big Bang.

Shortly thereafter, Edwin Hubble affirmed Slipher's findings. In 1929, Hubble calculated that the most distant galaxies were traveling away from the Milky Way at tremendous speeds. His work eventually resulted in what is known as Hubble's law: the recession velocity of a galaxy is proportional to its distance from our solar system; the more distant the galaxy, the faster it is receding into space.

By the 1940s, George Gamow, Ralph Alpher, and Robert Herman correctly predicted the abundance of the two most basic and prevalent elements in the universe — hydrogen and helium. Gamow also held that all of the radiation present in a primordial universe would not simply dissipate as the universe expanded. That belief set the stage for the serendipitous discovery of the CBR in 1964 by two Bell Telephone Laboratory scientists, Arno Penzias and Robert Wilson, who had been looking for sources of possible interference of satellite transmissions. At certain frequencies, they encountered puzzling emissions that seemed to come from every direction in which they pointed their microwave horn antenna. After many exhaustive tests were made, a colleague told them about the theories concerning the undetected CBR, and it was soon realized that what they were observing was in fact the dying glow of the primeval fireball.

The Origin of the CBR

As interpreted by most cosmologists, the origin of the cosmic background radiation was the Big Bang. Now, some 15 or 20 billion years later, the afterglow of that explosion has been observed at many wavelengths coming equally from all directions. It is the most pervasive radiation in the universe and does not have a natural explanation through another theory.

When the primordial explosion occurred, says Mather, it began an exponential expansion of space. "It was not just coasting outwards, it was accelerating as it went in a way that has not been acceptable in modern physics, until recently."

Immediately after the explosion, the temperature began to drop, plummeting to 10 million degrees Kelvin within minutes. As the universe cooled, Helium nuclei began to form. But just as quickly as complete atoms tried to assemble, the intense primordial radiation tore them apart. This continued for about 500,000 years until the universe cooled to a tolerable 3,000 K, allowing protons and helium nuclei to capture electrons. As complete atoms formed, the seething mixture of intense radiation and independent particles suddenly began to clear. Hydrogen and helium were formed and the gas began to feel the effects of gravity. At this point, protogalaxies (the predecessors of today's galaxies) began to form. Cosmologists refer to this milestone as the "decoupling" because before this point, matter and radiation shared a common temperature and were bound together tightly, like grains of sand in a barrel of molasses. Once sufficient water (in this case stable atoms) was added to the barrel, the molasses and sand went their separate ways.

The isotropic characteristics of the universe were set at the time of decoupling. A scant 250 million years later, stars and galaxies formed as the temperature of the universe dropped to 200 K, and the universe we see today was well on its way.

COBE's FIRAS, DMR, and DIRBE Experiments

COBE's three highly specialized instruments will be able to recognize the CBR by its 3-degrees Kelvin thermal energy distribution, which has been redshifted by 15 billion years of expansion. Although it carries this distinctive earmark, the enfeebled CBR, once hotter than 100 billion Suns, is now so faint that COBE's instruments must be housed in a Dewar flask filled with liquid helium and cooled to a frosty 2 K. Such extreme refrigeration is necessary because of the sensitivity of COBE's instruments. The FIRAS, for instance, can detect 0.01 trillionth of a watt per second.

COBE's FIRAS is designed to scan the 0.1 millimeter- to 10 millimeter-wavelength range, covering about 1,000 points in the sky. Similar instrumentation has been used extensively in the past in high-altitude balloon and rocket flights, with varying results. The design of COBE's FIRAS was eleven years in the making, and actual fabrication of the instrument began almost five years ago.

The FIRAS uses an interferometer with two ports: one is fed by a trumpet-shaped antenna that receives radiation from the sky, and the other is fed by a reference horn that has a black body calibrator covering its aperture. The "sky horn" can occasionally be covered with a movable, cone-shaped black body calibrator that can be set to any temperature between 2 and 20 K, that traps 99.99 percent of the light that strikes its surface. Therefore, the radiation it emits is known to depend only on its surface temperature. According to Mather, "It is constructed to be the best black body we can build."

The black body simultaneously radiates energy toward the instrument's detectors by a separate but identical path traveled by the radiation from the sky. The entire FIRAS optical configuration is symmetrical: if the reference black body is exactly as bright as the sky, there cannot be any variation in the amount of radiation that reaches the detectors. So the FIRAS looks for the difference in brightness between the reference black body and that coming from the sky.

Next, a moving interferometer mirror is employed that encodes the signals from the sky by modulating them into a frequency range that varies from 1 to 100 cycles per second. FIRAS then relies on a set of internal mirrors to redirect and refine the image of the light traveling through the instrument.

Ultimately, the light falls on two pairs of bolometers — not unlike thermometers — that measure energy by the resulting increase in their temperatures. This in turn produces an electrical signal from each detector that is amplified electronically, digitized, and sent to FIRAS's on-board microcomputer.

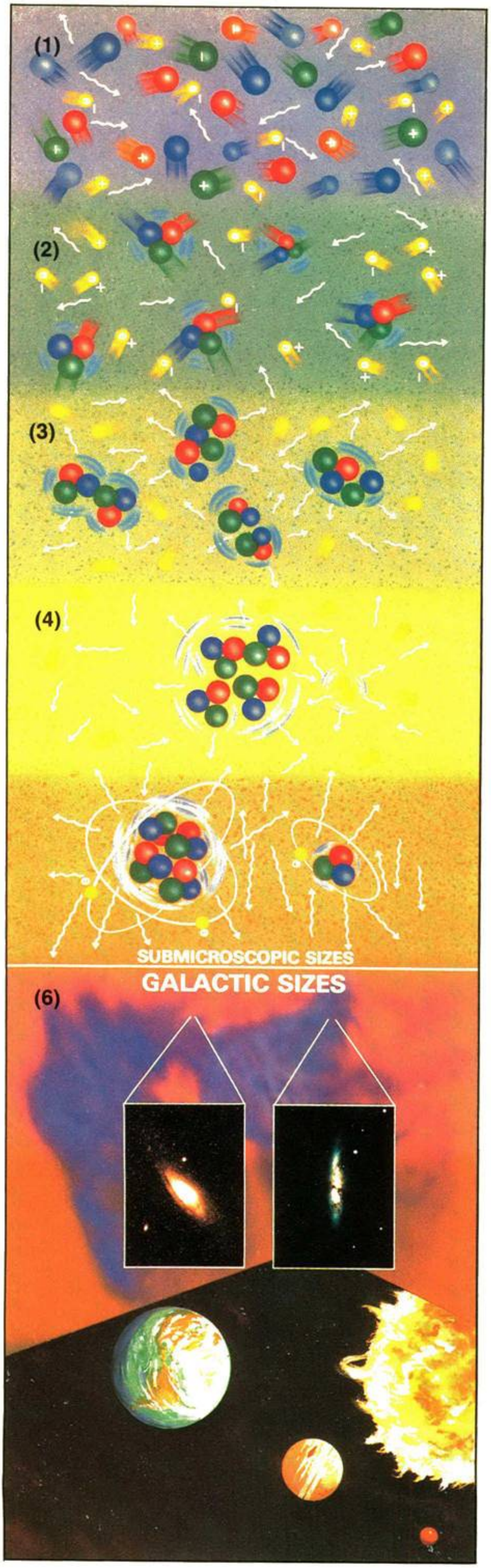
George Smoot has been working with DMRs, COBE's second instrument, since the days they were designed to fly in U-2 aircraft. The primary mission of the DMR, he says, is to "detect and map large, angular-scale anisotropies in the cosmic background radiation by generating a sensitive sky map." The map will be based on a search at wavelengths of 9.5, 5.7, and 3.3 millimeters (31.4, 53, and 90 GHz, respectively), where Smoot hopes to find evidence of turbulence, anisotropic expansion, and galactic formation present in the embryonic universe.

Smoot explains that there are two ways to collect data with a DMR: "The first is to sweep the antenna across the sky very quickly and sum up all the data and scan over and over again. Or, you can use the technique we are trying [with COBE]. We have two antennas and a switch at the bottom that switches the input to the receiver back and forth between the antennas. The antennas point at different places in the sky and the receiver looks at the difference in power received."

The signal to the receiver chops back and forth very quickly, and a synchronous demodulator looks for a signal that varies in phase and in time with the switch. Because the DMR generates more noise than the cosmic background radiation, Smoot uses the rapid chopping action to average out the noise of the receiver.

Although all three of COBE's instruments carry internal reference sources, the DMR uses the Moon for its primary reference source. "The Moon," says Smoot, "is always where you need it, when you need it." But the DMR also carries a second calibrator in the form of a noise source that can be turned on and off electrically. "We have a couple of things in there that allow us to add a little noise to aid in the calibration of the instrument," says Smoot. "We have some noise sources with effective temperatures of 60,000 K, and we couple them into the bottom of the antenna, where they give an effective signal between 1 K and 2 K. That gives us a big enough signal to calibrate it on."

After the signal enters the DMR through its two horn-shaped antennas and a Dicke switch alternately samples each antenna, it is then mixed with a signal from a local oscillator to create an intermediate frequency signal. This step is necessary because the radiation that the scientists are looking for generates a signal measuring only three-thousandths of a degree Kelvin, or about 10^{-14} watts — a tad faint. With the added signal, it is amplified about 100 million times to 10^{-6} watts, which is in a range that the on-board diode detector can pick up. Another amplifier boosts the signal even more and then it is digitized for transmission to the ground where it is processed through the COBE project's computer. After a year of continuous observations, COBE's DMR will have collected the equivalent of a



(1) Cosmologists can trace the origin of the universe back to between 10^{-43} to 10^{-33} of a second after the Big Bang, when matter consisted of a super-dense sea of quarks and elementary particles. (2) In the 10^{-6} to 10^{-3} seconds that follow, quarks that have not been annihilated by antiquarks combine to form protons and neutrons. (3) This is followed by a period of antimatter annihilation between 10^{-3} and 100 seconds. (4) The formation of helium nuclei occurs during the next 3 minutes. (5) For the next million years, the universe cools down enough that protons can capture electrons to form the first hydrogen and helium atoms. (6) This epoch is followed by the matter-building period, 1 billion years after the Big Bang to the present, during which galaxies are formed followed by stars, planets, and living organisms.

staggering one microwatt-second of energy.

It is much more difficult to study the diffuse radiation of the Big Bang than it is to look at discrete radiational sources like stars and galaxies. These point sources can potentially bias the readings made by the sensors receiving radiation from large areas of sky. Fortunately, COBE's third instrument, says Dr. Michael Hauser, principal investigator of the DIRBE instrument team, "is designed for very strong rejection of off-axis sources of light. The whole optical configuration is laid out to eliminate radiation that is not coming directly from DIRBE's field of vision."

The DIRBE, like the FIRAS, carries an internal source to monitor the performance of its detectors when the instrument is not looking at the sky. The instrument uses a series of small resistors that are electrically heated until they are warm enough to be detected by DIRBE's sensors. The radiation generated by the resistors is then processed through a small maze of mirrors until it is reflected into a secondary mirror, where DIRBE treats it as though it had come from the sky.

When the DIRBE opens its receivers to the heavens, a stray-light stop near the secondary mirror limits the field of view to one degree square. Stars and other discrete sources within that field are imaged a few inches in front of the secondary mirror. Farther down the light path, a second stop prevents the detectors from seeing the edge of the primary mirror, thus limiting diffraction effects. A third stray-light stop reduces the field even more, to seven-tenths of a degree square. Then the image is reflected from a tertiary mirror to a pair of flat mirrors mounted on the prongs of a tuning fork that vibrates 32 times a second. The light next encounters a "chopper" that, when open, allows the image to pass through to the DIRBE detectors or, when closed, allows the detectors to see only a DIRBE-generated "cold beam stop."

"The DIRBE is designed to measure the difference between zero radiation entering the detectors from the cold stop and that from the sky," says Hauser, "which makes it an absolute radiometer." The DIRBE compares the known characteristics of the cold beam stop with those of the meticulously selected image of the sky that works its way through the labyrinthine optical configuration.

Since the signal from the sky is interrupted 32 times a second, DIRBE's detectors look for a signal with a frequency of 32 cycles a second — in phase with the chopper. This chopper helps DIRBE's mission in two ways: it eliminates noise that may be present in the detectors, and it enables scientists to analyze a signal that could only have come from the sky. The cold beam stop is kept at 2 K to prevent it from creating radiation that might interfere with the experiment.

Once through DIRBE's maze of mirrors, the light must pass on to photoconductors, photodiodes, and bolometers deployed in an array of sixteen detectors. The measurements taken by the final array of detectors go to DIRBE's tape recorder. When COBE has received input from all of its instruments, it transmits the data back to Earth for analysis.

The diffuse glow created by interplanetary and interstellar dust could seriously complicate the DIRBE observations, as well as those made by the other COBE instruments. Interplanetary dust is heated by the Sun to temperatures around 300 K, but it cools off by radiating in the infrared at the same wavelength that the DIRBE will be using to look for the diffuse glow from early stars and galaxies. Interstellar dust, heated by the stars to temperatures of 10 K to 300K, also cools itself by radiating at wavelengths that COBE's instruments will be exploring.

Fortunately, both kinds of dust have conspicuous characteristics: interplanetary dust is smoothly distributed across the sky; interstellar dust is not as bright but is clumpy and confined largely to the galactic plane. Once the radiation signatures of both interplanetary and interstellar dust are recorded and accounted for by COBE's instruments, they can be "subtracted" from the total, leaving only that radiation emanating from the cosmic background.

The Space Telescope and Beyond

It's only natural to wonder if the accomplishments of humble COBE will pale in comparison to the splashy, show-stopping Hubble Space Telescope, which is slated to precede it into space. Mather doesn't think so.

"The Space Telescope will help us interpret our data and we will help them interpret theirs," says Mather. "They will be able to catalogue all the things that make radiation . . . at the wavelengths they study, which are mostly visible and ultraviolet light. Those objects are at temperatures of thousands of degrees. COBE is interested in studying things a lot cooler than that.

"A lot of the cool things we see are associated with the hot things that they see. Quasars, for instance, are incredibly bright objects — brighter than a galaxy of a hundred billion stars. And they emit x-rays, so portions of them are at millions of degrees; they emit optical light, and of that what we see is at thousands of degrees; they emit infrared light, so portions of them are at hundreds of degrees; and they emit microwaves and radio waves too."

The Space Telescope promises to return impressive, possibly even profound, photographs of visible objects in the universe. COBE on the other hand, will travel through space as a cosmic cartographer, sending back two complete "maps" of the sky and taking readings at almost 100 wavelengths ranging from 1 micron to 1 centimeter. COBE's maps will be very unlike the photographs returned by the Space Telescope, but they promise to be no less dramatic.

COBE will collect its data by scanning across the sky with the fine point of a small beam aimed successively at many points and will then make a picture out of all those points. "From those maps," says Smoot, "we hope to determine what the cosmic background radiation looks like, as well as the angular distribution of the radiation."

The Space Telescope will be able to look at individual objects at great distances, but COBE's radiation-seeking sensors will have to look through "windows" of reduced luminosity in the ubiquitous glare of interstellar clouds to obtain the best view of the universe. COBE's strategy is to sweep the heavens and examine the cumulative glow created by all things that exist. Cosmologists will be delighted if the Space Telescope can see as far back as the early universe, but Mather suspects conditions were probably very "murky" during that time, which may prevent scientists from using the fine resolution expected from this instrument.

Smoot adds, "Quite often you will see a fog bank sitting right inside the Golden Gate . . . and you can see everything clearly right up to the fog bank, you can kind of see a tiny way inside the fog bank, and beyond that you can't see anything." That's similar to what COBE will have to contend with, but the cosmic fog COBE will be looking at is 15 billion years old and very, very, faint.

Yet after all this a nagging question remains: What precipitated the primeval fireball and why did it happen? Perhaps that question is better left to theology since there is no scientific answer we can understand. Says Mather: "The gravitational forces in the primeval fireball were so intense that it produced a space-time warp in which modern physics breaks down. The temperatures were so high that the energy of the particles themselves were enough to distort the fabric of space and time, at which point you need a theory of quantum gravity, which we haven't got."

By the same token, most astronomers believe it is futile to muse over conditions prior to the explosion because, as Mather notes, "How can you talk about an event that occurred at a time when there was no such thing as an event?"

COBE is a product of the enormous strides made in cosmology in the last eighty years, and the mission would not be possible were it not for the dedication of hundreds of scientists and engineers. Perhaps in eighty more years, armed with the results from COBE and other CBR missions to follow, we will be able to reach into that primeval fireball and pull out the answer to "what." Maybe even "why."

Claude J. Bauer is a computer and data processing consultant for technical and scientific professionals. He also writes and publishes articles on science and technology.

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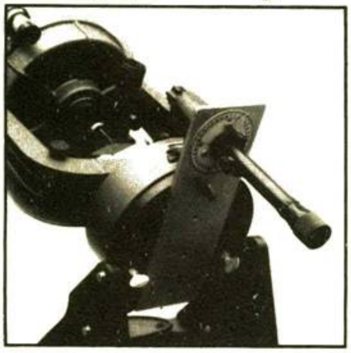

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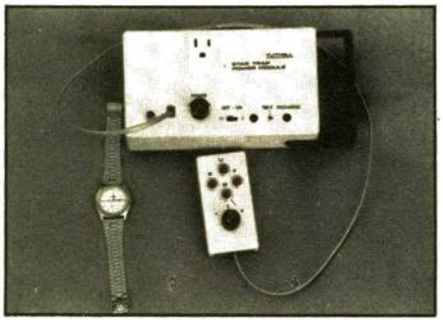

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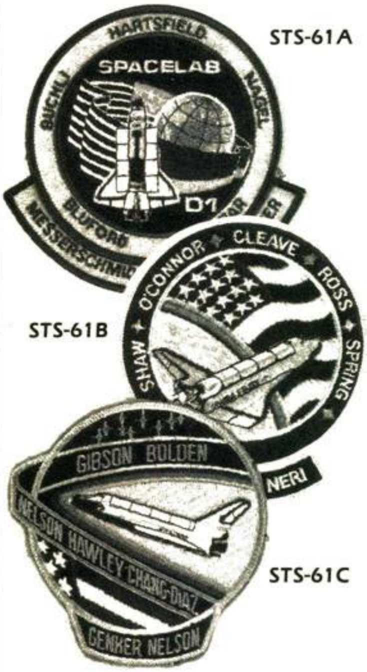

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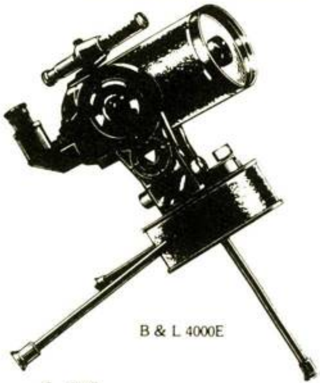
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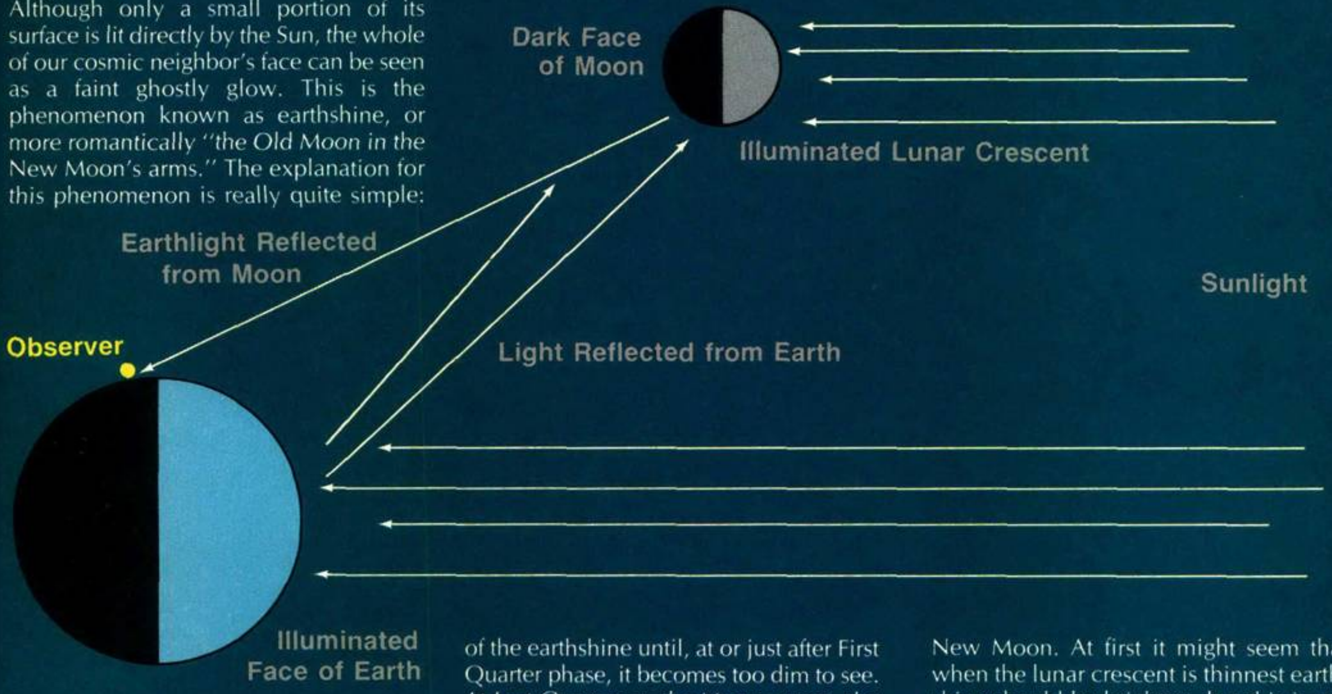
Some Reflections on Earthshine

Gazer's Gazette

by Clive Gibbons

Imagine a clear fall morning just before dawn with a thin crescent Moon hanging above the softly glowing horizon. After a long night's observing, you turn your telescope toward twilight and gaze at that illuminated sliver of our planet's companion. In a low-power eyepiece you enjoy the beautiful sight — the lunar surface pocked with craters and tinted yellow by earthly haze.

Then you notice something — something unique about the crescent Moon. Although only a small portion of its surface is lit directly by the Sun, the whole of our cosmic neighbor's face can be seen as a faint ghostly glow. This is the phenomenon known as earthshine, or more romantically *"the Old Moon in the New Moon's arms."* The explanation for this phenomenon is really quite simple: earthshine results when the "dark" portion of the Moon is lit by sunlight reflected from our planet.


Dark Face of Moon
Illuminated Lunar Crescent
Earthlight Reflected from Moon
Sunlight
Observer
Light Reflected from Earth
Illuminated Face of Earth

When the Moon appears as a thin crescent to an earthly observer, someone standing on the Moon would see our Earth as nearly fully lit. We all know how bright our landscape appears when the harvest Moon lights up those late fall evenings; just imagine how much brighter a Full Earth would appear to Moon dwellers! The Earth fills an area of the lunar sky over thirteen times larger than the Moon fills in our sky. And since the Earth is three times more reflective than the Moon, the Full Earth in the lunar sky shines forty times brighter than the Full Moon shines in the terrestrial sky.

As the Moon waxes in phase, Earth's phase wanes. This reduces the brightness of the earthshine until, at or just after First Quarter phase, it becomes too dim to see. At Last Quarter, as the Moon wanes, the Earth becomes Full in the lunar sky and the ghostly glow of earthshine brightens as the Moon becomes a very old crescent, approaching New once again.

The best times of year to see earthshine are when the crescent Moon stands highest in the sky. This happens when the ecliptic is most steeply inclined to the horizon, such as before sunrise on autumn mornings or in the spring evening sky.

You can enhance your view of "the Old Moon in the New Moon's arms" by using low-power optics. Big binoculars, those in the 80mm aperture range, or a small reflector or refractor giving 20x to 40x magnification work best. Large telescopes generally have too narrow a field of view to fit the whole image of the Moon in comfortably. Filters don't help since they only dim the image.

Several factors affect the brilliance of earthshine. It reaches maximum visual intensity two to three days before or after New Moon. At first it might seem that when the lunar crescent is thinnest earthshine should be brightest, but this is not so. During the crescent phase, the Moon is much closer to the Sun in the sky and is overwhelmed by bright twilight. Horizon haze also dims the lunar light more strongly.

The fat crescent four to five days before or after New Moon is higher in the sky and less affected by haze and twilight, but the brightness of Earth drops rapidly after the Full phase. The strength of reflected earthlight is thus reduced. Furthermore, the brilliance of the Moon's sunlit surface

Overleaf: Two and a half days after New Moon, the blue glow of earthshine illuminates the familiar features of our satellite's surface inside the greatly overexposed image of the lunar crescent. For this 5-second exposure with an 8-inch f/10 SCT, Clive Gibbons used ISO 400 film push-processed to an ISO 800 rating.

dazzles the much more subtle earthglow. The net result of these various effects is that earthshine peaks two or three days before and after New Moon.

However, the actual brightness of earthshine depends on another factor. Since earthshine depends on light reflected from Earth, changes in our planet's reflectivity play a role. Clouds, ice, and snow certainly reflect much more light than dry land and the ocean. If you were standing on the Moon, when would you expect to see the greatest area of clouds, ice, and snow on Earth?

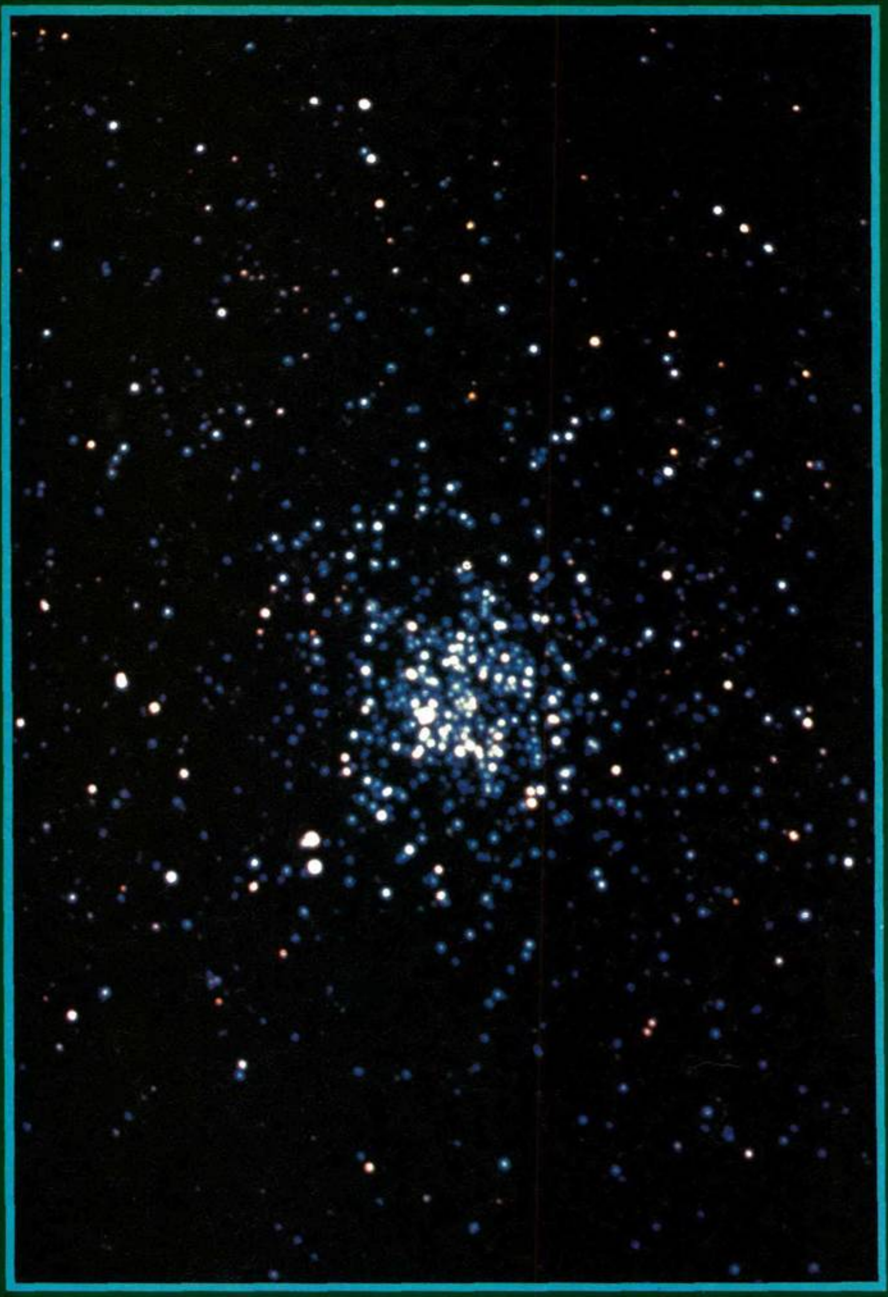
The answer is during mid-winter in the Northern Hemisphere. During this time, the Northern Hemisphere is dominated by clouds and snow covers much of the northern continents. Antarctica is in nearly perpetual sunlight during northern winter, so it's easy to see why Earth is then at its brightest and earthshine is most prominent. My own observations during winter seem to confirm this hypothesis.

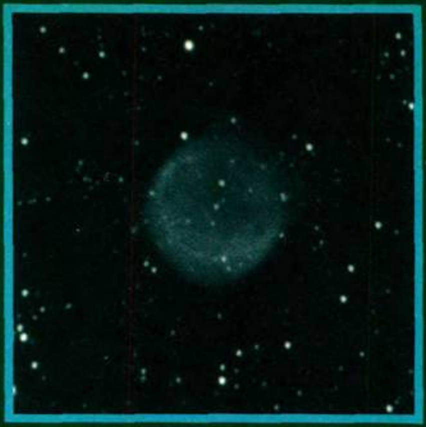
What is the most unusual time to see earthshine? During a total solar eclipse, of course. The Moon is New and thus the Earth is Full, except for the shadow that the Moon casts on its surface. However, earthshine is rarely reported at these times. The culprit is the glare of the solar corona, which easily masks the more elusive earthshine. Photography is much more successful than visual observing for showing this phenomenon. Exposures of a few seconds, intended to capture the faint outer parts of the corona, often record the outlines of seas and highlands on the lunar face, too.

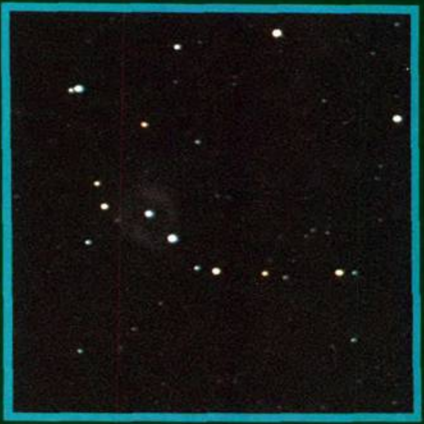
Under ordinary morning or evening circumstances, the faint glow of earthlight beside the crescent requires a 10-second exposure at f/10 on ISO 400 film. To prevent trailing with focal lengths over 500mm, you'll need a fairly accurate clock drive. However, you'll need only a ½-second exposure using a 200mm f/3.5 lens and ISO 1600 film, and you won't need a drive to keep the image sharp. With a short-focus lens, though, the lunar image will be small. Color film shows the earthshine to be distinctly bluish — not surprising when you consider its light source is "the blue planet."

Next time the sky is clear and a thin slice of Moon is smiling in the soft twilight, take a closer look for this phantom light that haunts its face.

Clive Gibbons is an amateur astronomer living in Ontario, Canada. He writes: "I've always loved photographing the crescent Moon with its earthshine. Here's hoping this essay will inspire a few others to follow the same path."





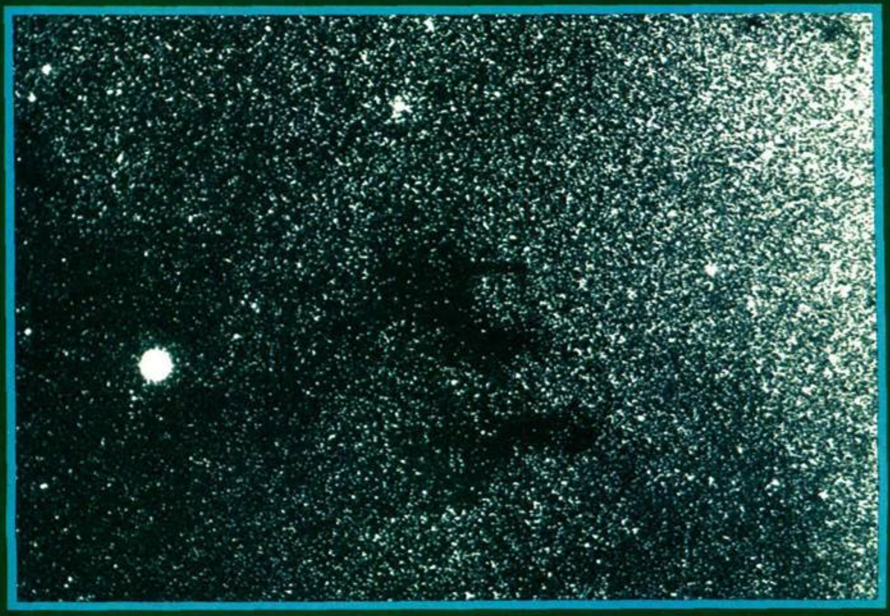


Above left: M-11, the Wild Duck Cluster, is one of the richest assemblages of stars in the summer sky and is resolvable in any telescope. Photo by Scott Rosen.

Top: NGC-6781 is a large, low-surface-brightness planetary nebula visible as a ghostly arc of light. Photo by Jack B. Marling.

Above: NGC-6804, another planetary of similar brightness, measures about half the size of NGC-6781. Photo by Jack B. Marling.

Left: The dark nebulae Barnard 142 and 143 form a distinctive "E" in the rich Aquila Milky Way. Photo by David Healy.



Aquila

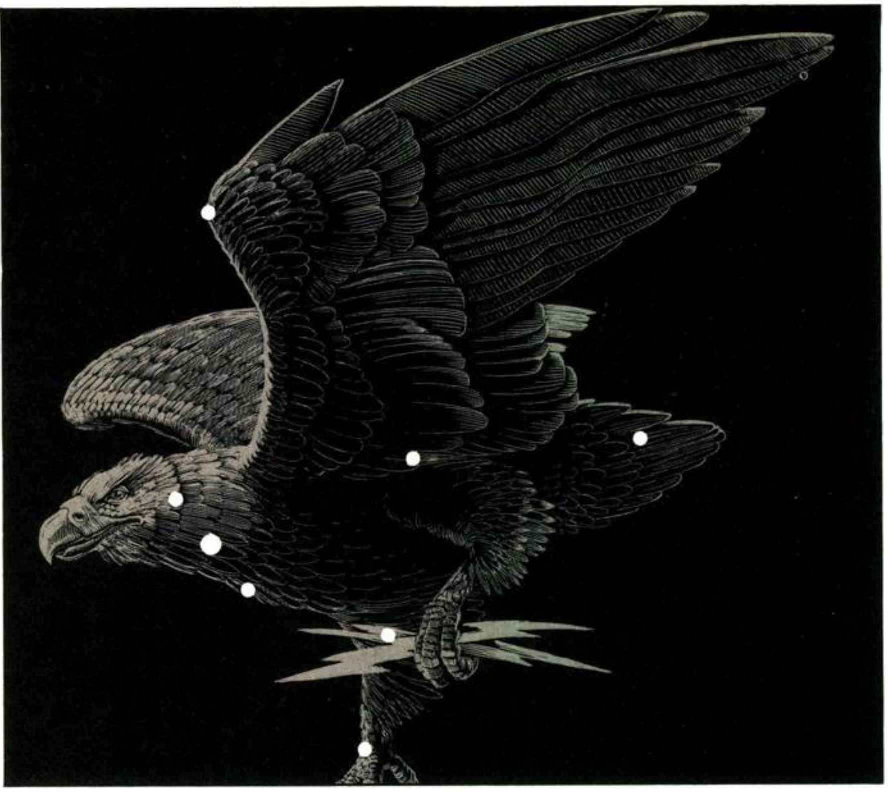
Aql

Aquilae

Scutum

Sct

Scuti



Keith Ward

Tucked between the barely noticeable constellations Delphinus and Sagitta to the north and the rich and impressive star clouds of Sagittarius to the south, **Aquila** the Eagle and **Scutum** the Shield are two of the summer Milky Way's finest offerings. Each contains several unique examples of bright deep-sky objects: Aquila offers abundant planetary nebulae and Scutum possesses bright open clusters.

The finest sight in Scutum is the brilliant open cluster **Messier 11** (NGC-6705), which lies on the northern edge of the Scutum starcloud. Discovered in 1681 by Gottfried Kirch at the Berlin Observatory, M-11 was then described as being a "small, obscure spot with a star shining through and rendering it more luminous." It is actually a large, rich, relatively distant open cluster composed of at least 870 stars brighter than magnitude 17.

At first glance, observers with small instruments may mistake M-11 for a globular cluster. In binoculars and finderscopes the group appears as a misty clump of nebulosity with only a hint of resolution — a grainy smattering of barely perceivable points of light. A 3-inch refractor at high power shows M-11 as a patch of tiny, faint stars some 10′ across, with one bright standout near the group's center. Larger scopes clearly show M-11's triangular shape and numerous glittering stars, an impressive sight that the great English observer Admiral Smyth likened to a group of wild ducks in flight.

M-11's total magnitude is 5.8 (visible to the naked eye under a very dark sky), and its brightest star shines at magnitude 8.0. Since the cluster lies some 1.7 kiloparsecs distant, it and the other brightest members must be very luminous giants to shine as brightly as they do. If the Sun were placed at M-11's distance it would shine at barely 15th magnitude.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

Since the cluster is one of the richest of its type, the density of stars in M-11 has been the subject of discussion for decades. It appears that there are some 83 stars per cubic parsec in M-11. An observer inside the group would see several hundred 1st-magnitude stars in his night sky.

About 30′ northwest of M-11 are two 6th-magnitude double stars. Another 30′ northwest of these two doubles and 1° south of Beta (β) Scuti is the peculiar semi-regular variable star **R Scuti**. This ruddy star's variability was discovered by the English observer E. Pigott in 1795, and it has since become one of the most widely observed variables in the sky. It is classed as an RV Tauri-type variable, one that shows a variety of complex behavior for several reasons.

Displaying at least two superimposed periods, R Scuti has a primary period of about 144 days, but its amplitude is somewhat variable. Occasionally it reaches magnitude 4.8 and drops to magnitude 6.0. Sometimes the star fades to fainter than magnitude 8 at minimum. R Scuti also shows a long wave-like cycle of some 1,300 days.

Try observing R Scuti every week or so this summer. Using binoculars or a small telescope, estimate its brightness relative to the surrounding stars in Scutum. Is it brighter or fainter than the two double stars to the southeast? By how much? Keeping a chart of R Scuti's magnitude will, over time, permit you to compile a "life history" of its behavior.

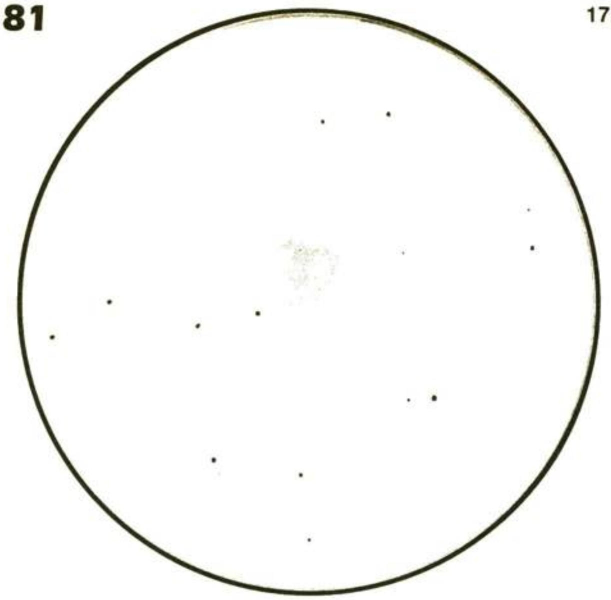
Three degrees south of the M-11/R Scuti area lie two more impressive objects. **M-26** (NGC-6694) is an open cluster that is often passed by because of its brighter neighbor to the north. But M-26 itself is a worthwhile object, as it contains thirty stars in an area spanning 15′ across for a combined magnitude of 8.0. The brightest star in M-26 glows at magnitude 10.3 — much brighter than the Sun would be at such a distance but many times fainter than the brightest stars in M-11.

Small telescopes show M-26 as a tightly-packed group of stars in a very rich field, with the brightest stars lying on the cluster's southwestern edge. Larger telescopes show progressively fainter stars strewn amongst the primary cluster members, but they don't greatly enhance the view of this little group of suns.

Two degrees east and a little north of M-26 is the fine globular star cluster **NGC-6712**. Measuring 7.2′ in diameter and shining at magnitude 8.2, this object is a fine sight in any telescope; it even appears as a moderately large disk of gray light in finderscopes. A 6-inch scope at high power resolves the edges of NGC-6712, which lies some 7.6 kiloparsecs away and is rather heavily obscured by galactic absorption. Large scopes resolve some stars across the face of the cluster, making them appear suspended on a background of misty nebulosity. Within the same low-power field is the faint planetary nebula **IC 1295**, which measures some 90″ across but

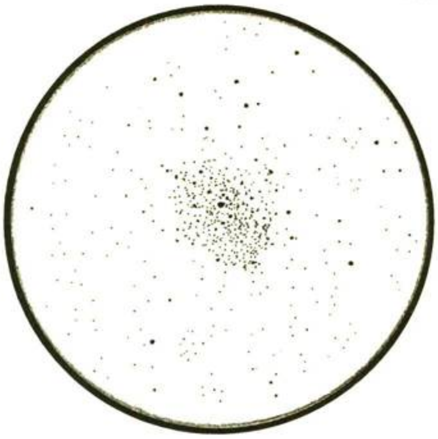
NGC-6781

17.5-inch f/4.5
reflector
71x



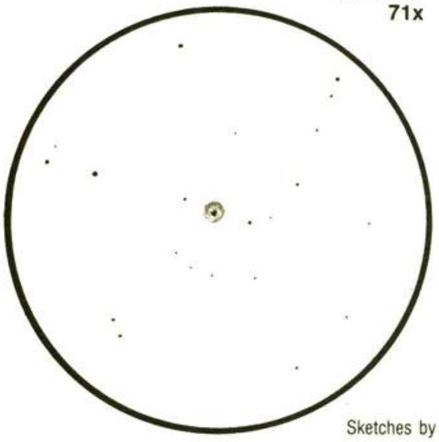
M-11

8-inch f/10 SCT
100x



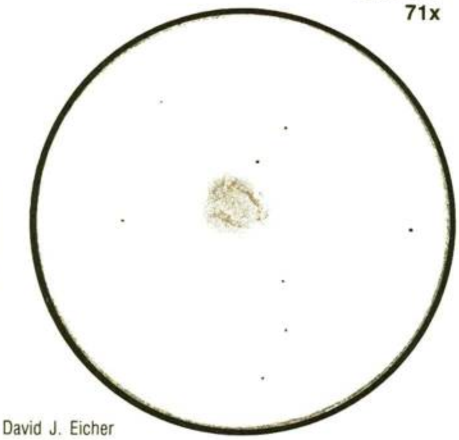
NGC-6751

17.5-inch f/4.5
reflector
71x



NGC-6772

17.5-inch f/4.5
reflector
71x



Sketches by David J. Eicher

glows dimly at 15th magnitude.

Near the center of the constellation Scutum lies Alpha (α) Scuti, the star group's 4th-magnitude luminary. In the same low-power field, just to the east, is the bright, scattered open cluster **NGC-6664**, which contains fifty stars in an area spanning 16′. At a distance of 1.3 kiloparsecs, this cluster is closer than M-26, and its brightest star shines at magnitude 10.2. A small telescope at low power is all that's required to view NGC-6664 comfortably; larger scopes show a few additional members in the group but generally decrease the field of view.

Unlike Scutum, Aquila contains numerous planetary nebulae observable in backyard telescopes. The best is **NGC-6781**, a giant, ring-shaped nebulosity glowing at photographic magnitude 11.8. NGC-6781 measures some 109″ — nearly two arcminutes — across, so its surface brightness is pretty low. Observe it using medium powers on a very dark, transparent night. Under those conditions you should pick it up in a 4-inch or 6-inch telescope with little trouble.

Three-and-a half degrees northeast of NGC-6781 is the slightly fainter nebula **NGC-6804**, lying just southwest of a 7th-magnitude double star. NGC-6804 glows at photographic magnitude 12.2 and measures a mere 31″ across, giving it a much higher surface brightness than NGC-6781. In the southern part of Aquila lies **NGC-6772**, a one-arcminute diameter planetary faintly glowing at photographic magnitude 14.2. About 4° southwest of NGC-6772 is the bright, diminutive planetary **NGC-6751**, a photographic magnitude 12.5 object measuring only 20″ across.

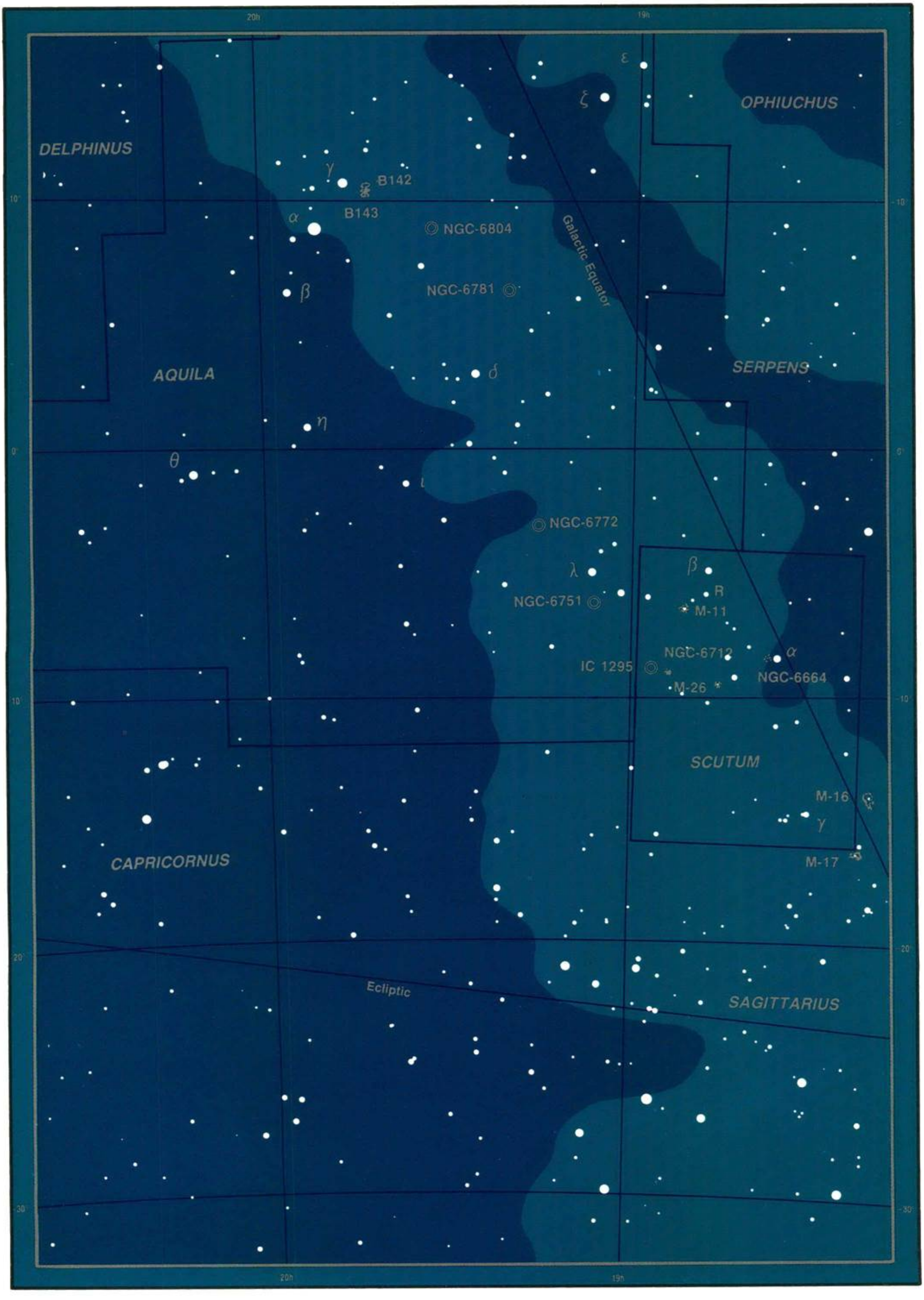
About 3° northwest of Altair, Aquila's brightest star, is the stark and easily observed dark nebulae **Barnard 142** and **B143**. These two entries from E.E. Barnard's catalogue of dark nebulae form a giant "E" shape some 80′ x 50′ in extent, through which very few stars shine. Try observing it with a low-power eyepiece — you'll be delightfully surprised.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	N★
NGC-6664		⊙	18h 36.7m	−8°13′	7.8	16′	50
NGC-6694	M-26	⊙	18h 45.2m	−9°24′	8.0	15′	30
R Sct		SRV	18h 47.5m	−5°42′	4.5↔8.2	144d	
NGC-6705	M-11	⊙	18h 51.1m	−6°16′	5.8	14′	
NGC-6712		●	18h 53.1m	−8°42′	8.2	7.2′	
IC 1295		■	18h 54.6m	−8°50′	15.0_P	86″	
NGC-6751		■	19h 05.9m	−6°00′	12.5_P	20″	
NGC-6755		⊙	19h 07.8m	+4°14′	7.5	15′	100
NGC-6772		■	19h 14.6m	−2°42′	14.2_P	62″	
NGC-6781		■	19h 18.4m	+6°33′	11.8_P	109″	
NGC-6804		■	19h 31.6m	+9°13′	12.2_P	31″	
B142/B143		□D	19h 40.7m	+10°57′	—	80′x50′	
NGC-6814		§	19h 42.7m	−10°19′	11.2	3.2′x3.0′	

SRV	*Semiregular Variable Star*
⊙	*Open Star Cluster*
●	*Globular Star Cluster*
■	*Planetary Nebula*
□D	*Dark Nebula*
§	*Spiral Galaxy*

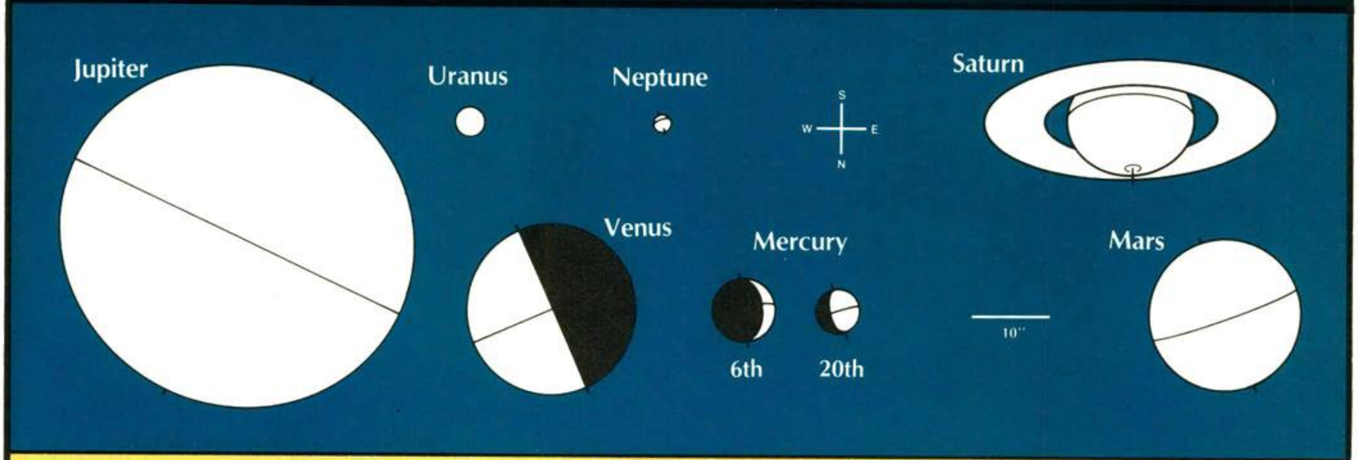
N★ = Number of stars in the cluster

Subscript "P" denotes photographic magnitude; subscript "B" denotes blue magnitude.

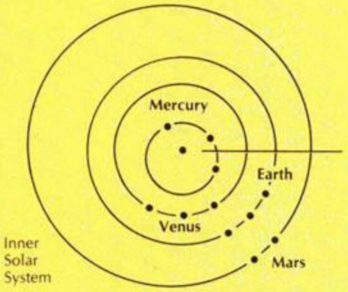

20h
19h
ε
ζ
OPHIUCHUS
DELPHINUS
γ
B142
B143
10°
α
NGC-6804
Galactic Equator
β
NGC-6781
AQUILA
SERPENS
δ
η
0°
θ
ι
NGC-6772
λ
β
R
NGC-6751
M-11
NGC-6712
α
IC 1295
NGC-6664
M-26
-10°
SCUTUM
M-16
γ
CAPRICORNUS
M-17
-20°
Ecliptic
SAGITTARIUS
-30°
20h
19h

Planetary Data

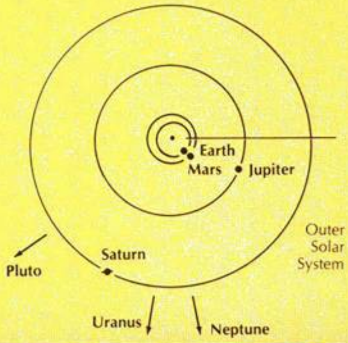
August 1986


Jupiter
Uranus
Neptune
S
W
E
N
Saturn
Venus
Mercury
6th
20th
10''
Mars

	Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Distance (AU) from: Sun	Longitude: Heliocentric	Longitude: Ecliptic	R.A. (2000.0)	Dec.
Sun	1	−26.7	31.6′	—	1.02	—	—	128°28.3′	8h 40.4m	18°21.0′
	15	−26.7	31.6′	—	1.01	—	—	141°53.6′	9h 37.8m	14°09.3′
	31	−26.7	31.7′	—	1.01	—	—	157°18.6′	10h 36.7m	8°45.7′
Mercury	1	2.5	10.1″	10%	0.67	0.39	330°07.7′	116°24.5′	7h 49.4m	16°57.3′
	15	−0.4	6.9″	53%	0.98	0.32	37°21.9′	123°58.3′	8h 23.6m	18°54.7′
	31	−1.5	5.1″	97%	1.32	0.33	134°22.3′	151°53.4′	10h 18.1m	12°27.2′
Venus	1	−4.2	18.7″	61%	0.89	0.73	249°39.1′	172°47.0′	11h 34.1m	3°09.7′
	15	−4.2	21.4″	55%	0.78	0.73	271°51.3′	187°37.4′	12h 26.8m	− 3°48.5′
	31	−4.4	25.6″	47%	0.65	0.73	297°09.5′	203°23.3′	13h 23.2m	−11°24.3′
Mars	10	−2.2	21.1″	95%	0.44	1.40	306°29.3′	281°45.4′	18h 52.9m	−28°36.0′
	20	−2.0	19.6″	93%	0.48	1.39	312°43.7′	282°07.1′	18h 54.4m	−28°13.9′
Jupiter	15	−2.8	48.3″	100%	4.07	4.98	345°25.6′	351°17.1′	23h 30.4m	− 4°46.6′
Saturn	15	0.5	17.0″	100%	9.75	10.00	248°49.1′	243°19.2′	16h 06.5m	−19°03.5′
Uranus	15	5.6	3.7″	100%	18.68	19.16	261°09.0′	258°45.9′	17h 10.5m	−23°03.2′
Neptune	15	7.9	2.3″	100%	29.56	30.24	274°43.9′	273°32.7′	18h 15.0m	−22°18.6′
Pluto	15	13.7	0.1″	100%	29.98	29.71	216°45.8′	215°07.0′	14h 32.5m	2°13.2′


Mercury
Earth
Venus
Mars

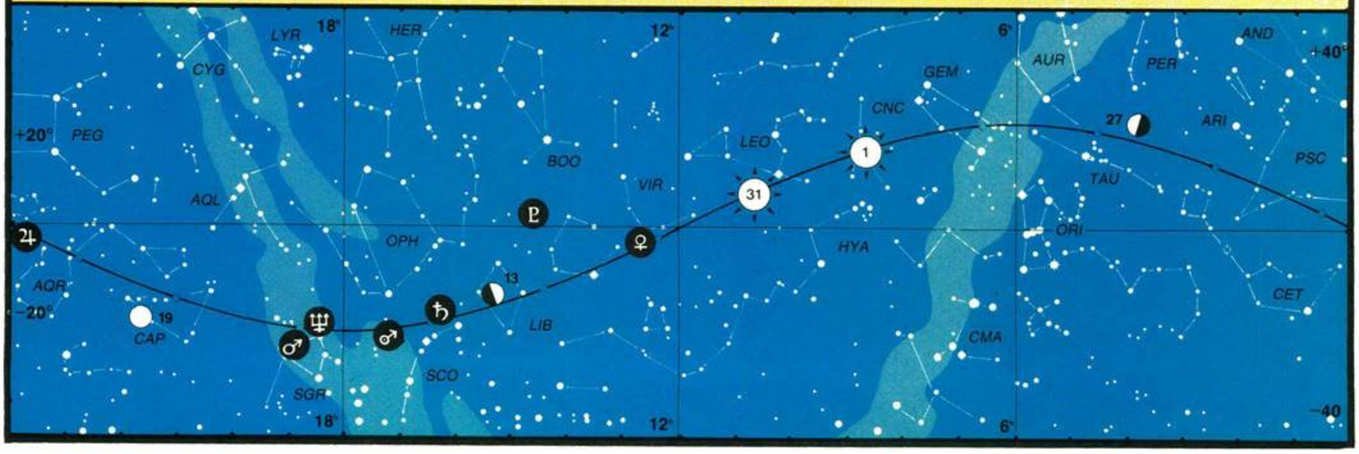
Inner Solar System

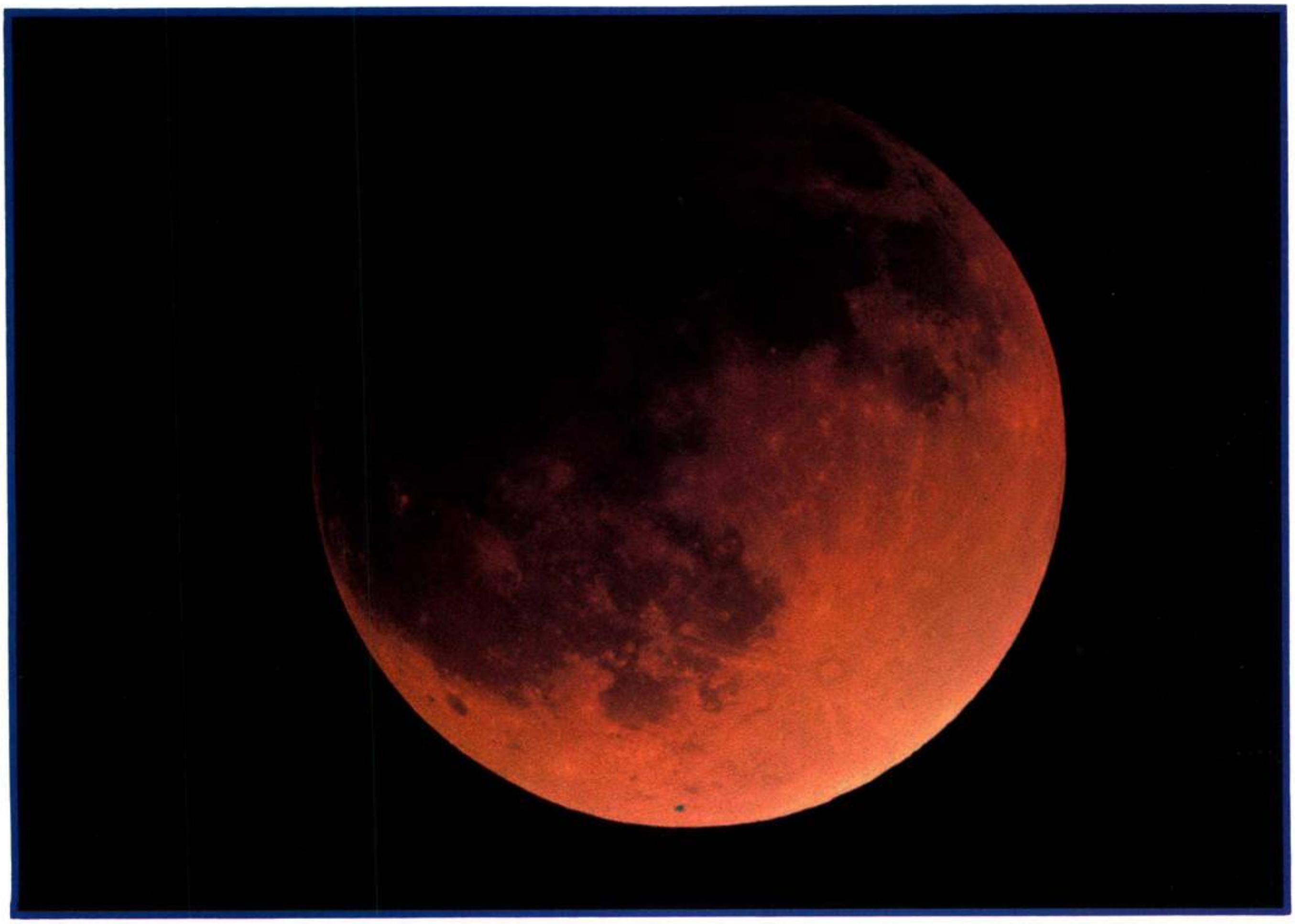

Earth
Mars
Jupiter
Saturn
Pluto
Uranus
Neptune

Outer Solar System

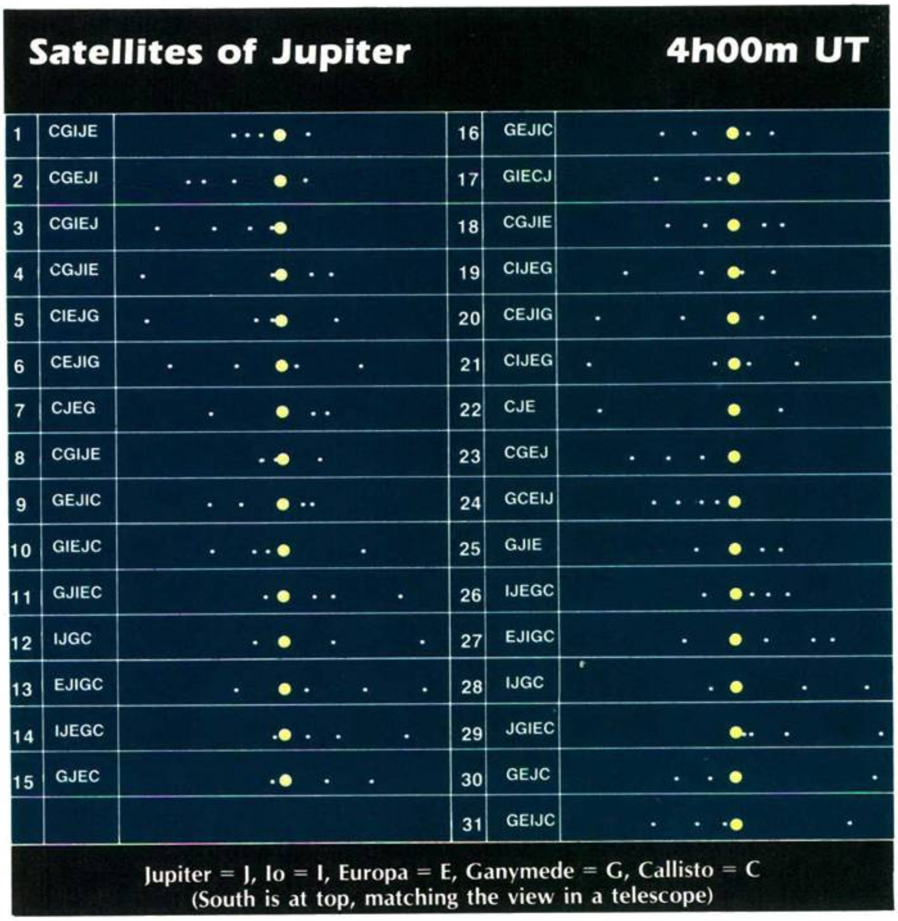
Moon Data

New Moon. . . . . August 5 at 18h36m
First Quarter. . . . . August 13 at 2h21m
Full Moon. . . . . August 19 at 18h54m
Last Quarter. . . . . August 27 at 8h38m
New Moon. . . . . September 4 at 7h10m
First Quarter. . . . . . . September 11 at 7h41m
Perigee: August 16 at 16h39m. 365,720 km.
Apogee: August 28 at 14h43m. 404,380 km.


LYR
18°
HER
12°
6°
AND
+40°
CYG
GEM
AUR
PER
CNC
27
ARI
+20°
PEG
LEO
1
PSC
BOO
TAU
AQL
VIR
31
♃
♇
ORI
OPH
♀
HYA
AQR
13
CET
−20°
19
♆
♄
LIB
CAP
♂
♂
CMA
SCO
SGR
18°
12°
6°
−40



The leading edge of Earth's shadow encroaches on Mares Nubium and Humorum in this photo of the lunar eclipse on April 24, 1986. The dark "spot" at lower left is the walled-plain Grimaldi, over 190 kilometers in diameter. The bright ray crater is Tycho. Photo by Jim Barclay.


Satellites of Jupiter
4h00m UT
1 CGIJE
2 CGEJI
3 CGIEJ
4 CGJIE
5 CIEJG
6 CEJIG
7 CJEG
8 CGIJE
9 GEJIC
10 GIEJC
11 GJIEC
12 IJGC
13 EJIGC
14 IJEGC
15 GJEC
16 GEJIC
17 GIECJ
18 CGJIE
19 CIJEG
20 CEJIG
21 CIJEG
22 CJE
23 CGEJ
24 GCEIJ
25 GJIE
26 IJEGC
27 EJIGC
28 IJGC
29 JGIEC
30 GEJC
31 GEIJC

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)

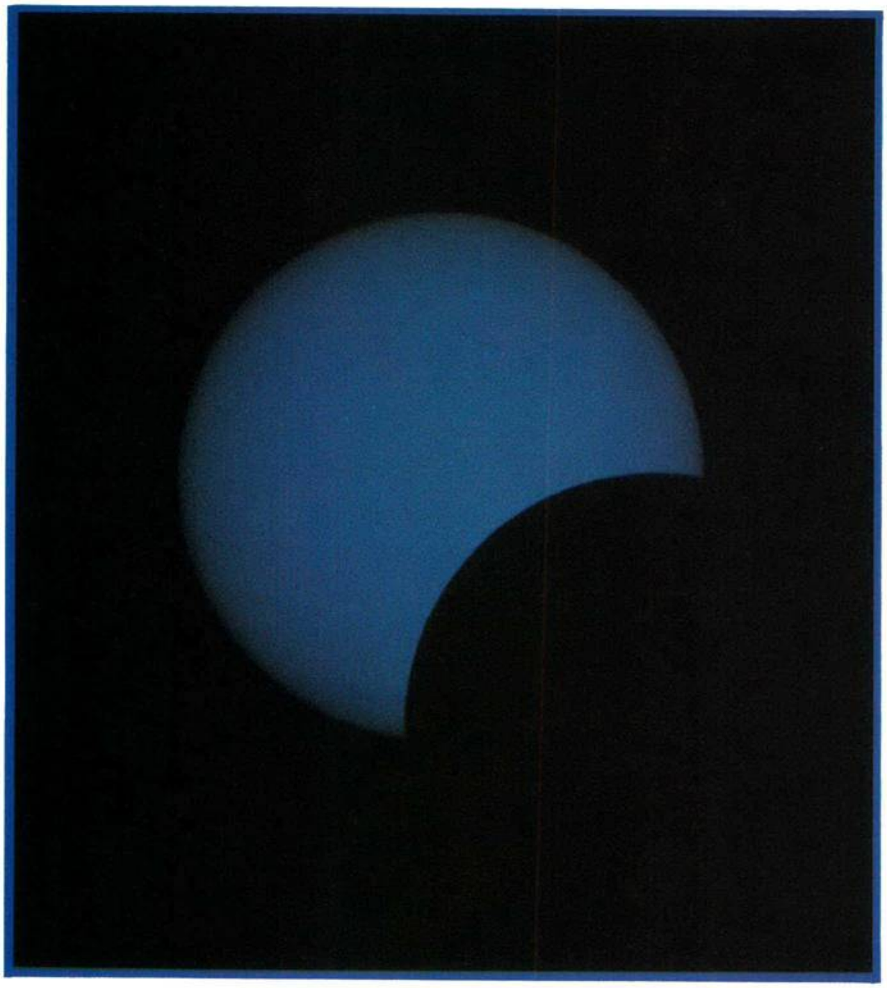
Mercury

Mercury is a morning object in August, reaching greatest western elongation from the Sun on August 11. Telescope users will find viewing it easiest from about the 5th until the 21st, during which time Mercury will be at least 5° high 45 minutes before sunrise. Peak elevation (8°) is on the 14th. In your eyepiece, you'll see Mercury dwindle steadily from 9.1" across on the 5th to 5.9" on the 21st.

If you locate Mercury in the morning twilight, continue viewing it while the sky brightens. As the planet rises above the murky air along the horizon and dawn lessens the contrast between planet and sky, see if you can discern any hint of Mercury's dusky markings. (They're extremely elusive, so don't be disappointed if you can't.)

Venus

In the evening sky, −4.3-magnitude Venus is at greatest eastern elongation on August 27 when it will be 9° high in the southwest 45 minutes after sunset. Although Venus' elongation from the Sun



Right: Victor Rojus wins the "Best Astrophoto" contest this month with his picture of Halley's Comet in Centaurus taken on April 9 with a 50mm f/1.8 lens on VR 1000 film.

Left: This shot of the April 9, 1986, partial eclipse of the Sun was made by Kim G. Rowe using 3M 1000 film, a 1200mm lens, and a 1/1,000-second exposure near Aryes Rock, Australia.

is a wide 46°, the planet still lies low in the sky because the ecliptic meets the sunset horizon at a shallow angle.

Viewing Venus over the next few months as it sinks toward inferior conjunction (November 5) will pose problems due to the planet's low elevation. You'll do best to locate Venus as close to sunset as you can and start observing before the sky is dark.

Mars

Nearly motionless in the handle of the Teapot of Sagittarius, Mars is well placed for telescopic viewing in the southeastern sky during the early evening. Unfortunately, the distance between Earth and Mars is increasing steadily (it grows by 15,700,000 kilometers this month) and Mars' apparent size is correspondingly shrinking. On August 1 Mars will be 22.3″ across (nearly what it was at opposition three weeks earlier), but by the 31st its diameter will have decreased to 17.8″. Take every opportunity you can to view the Red Planet this month, for soon it will be only a small, disappointingly bland orange disk in most telescopes.

Minor Planets

1 Ceres (magnitude 8.4) lies in central Virgo. Its positions:

1st: 12h 12m 03s, 7° 19.6′
10th: 12h 24m 42s, 5° 33.8′
20th: 12h 39m 09s, 3° 36.1′
30th: 12h 53m 58s, 1° 38.9′

Ceres sets around 10 p.m. local daylight time on the 15th.

2 Pallas is in conjunction with the Sun on September 23 and is out of sight this month.

3 Juno (11.1) is in western Ophiuchus near the 3rd-magnitude stars Epsilon (ε) and Delta (δ) Ophiuchi. Its positions:

1st: 16h 08m 41s, −5° 14.9′
10th: 16h 09m 54s, −5° 57.2′
20th: 16h 13m 04s, −6° 48.0′
30th: 16h 18m 00s, −7° 40.9′

Juno sets about 1 a.m. local daylight time at mid-month.

4 Vesta (6.8) lies in north-central Cetus. Its positions:

1st: 1h 15m 39s, −1° 29.9′
10th: 1h 19m 10s, −1° 49.2′
20th: 1h 20m 32s, −2° 26.5′
30th: 1h 19m 04s, −3° 19.0′

Vesta rises at midnight on August 15.

42 Isis (9.9) is moving retrograde near the common border of Microscopium and Sagittarius, reaching opposition on August 12. Its positions:

1st: 21h 37m 25s, −28° 18.9′
10th: 21h 30m 17s, −29° 51.6′
20th: 21h 22m 43s, −30° 59.9′
30th: 21h 16m 26s, −31° 34.1′

Isis rises around 9:30 p.m. local daylight time on the 15th and is visible until dawn.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star map (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that moved is it. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

Jupiter is at opposition in mid-September and can be found this month rising in the southeast soon after twilight has ended. On August 15, Jupiter's disk will measure 48.3″ across the equator, with a polar diameter of 45.2″. Jupiter appears larger now than it has for many years because it is approaching perihelion. This opposition and the next one in October 1987 will be especially favorable for viewing the planet since they fall closest to the date of Jovian perihelion, which occurs on July 10, 1987.

Even at fairly low magnifications (50x, say), Jupiter will display detail in the belts of racing clouds that form its visible disk. High powers used when the atmospheric seeing is good will reveal many smaller features. Look for "bridges" that span the light-colored zones and search for white spots in the dark belts.

Saturn

Saturn is now in the southwest as the sky darkens after sundown and has an elevation of about 25° during late twilight. Lacking the atmospheric activity that makes Jupiter so popular, Saturn has "only" its glorious ring system to offer as a viewing attraction. Between now and early November when the planet vanishes into evening twilight, Saturn's rings will be inclined 25° to our view. This month they spread about 38″ across.

Uranus

Although its 5.6-magnitude brightness puts it just within the limit of naked-eye viewing, Uranus is easiest to locate with binoculars or a finderscope. Start by centering on 3.3-magnitude Theta (θ) Ophiuchi (shown about an inch to the left of Antares on the Night Sky star map on pages 48-49), then look 3° to the northwest. You'll recognize Uranus by its bright green disk, which measures 3.7″ across and is distinctly non-stellar in appearance.

Neptune

To locate Neptune, start by finding Lambda (λ) Sagittarii, the 2.8-magnitude star at the top of the Teapot's lid. Then scan slowly northwest toward 3.9-magnitude Mu (μ) Sagittarii. Neptune lies about 1° southeast of Mu and has a grayish disk 2.3″ across at magnitude 7.9.

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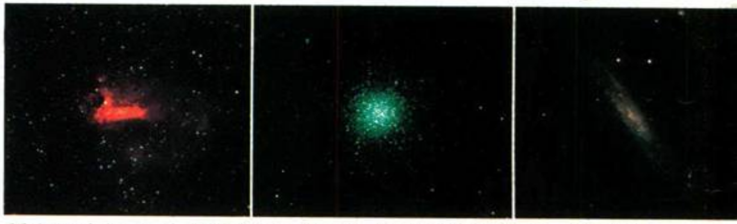

C8 Astrophotographs: M-17, Omega Nebula; M-13, Globular Cluster; NGC-253.

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